UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1026

Contribution from the Bureau of Public Roads
THOMAS H. MacDONALD, Chief

Washington, D. C. ▼ May 16, 1922

IRRIGATION IN NORTHERN COLORADO

By

ROBERT G. HEMPHILL, Irrigation Engineer

CONTENTS

(Based on data gathered under cooperative agreement between the Bureau of Public Roads of the United States Department of Agriculture and the Colorado Agricultural Experiment Station)

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CONTENTS.

INTRODUCTION.

Prior to the establishment of the Union Colony at Greeley, Colo., in 1870, only a few primitive attempts at irrigation farming had been made along the route of the Overland Trail in that State. The small acreage of less than 1,000 acres which was then irrigated for the purpose of raising native hay, vegetables, and grain for the mining camps has increased in the half century which has since elapsed to over 3,000,000 acres, yielding an annual revenue at current prices of over $100,000,000. This great increase in acreage has carried with it a corresponding development in irrigation practice and in the customs and laws relating to irrigation. In fact, Colorado, while maintaining a ranking in irrigation development second only to that of California, has established laws and customs and standarized practice to such an extent that the people of the State have become in many respects the leaders in such development throughout the Rocky Mountain region. In the aridity of its climate, elevation above sea level, topography, soils, and crops Colorado bears a close resemblance to several neighboring mountain States. It is not surprising, therefore, to find that the methods of preparing land and applying water as well as the laws and administrative systems of the State have been adopted by other States having somewhat similar physical conditions. The results of an irrigation investiga-

tion carried on for a number of years in the valley of the Cache la Poudre River in northern Colorado are herein presented in the hope that they will afford an opportunity for other communities possessing less experience to benefit by the principles and practice so successfully worked out in the Poudre River basin.

The investigation was carried on under a cooperative agreement between the Agricultural Experiment Station of Colorado and the Bureau of Public Roads, each party contributing equal amounts to the undertaking. At first the investigation was in direct charge of V. M. Cone, irrigation engineer, who, under the general direction and supervision of Samuel Fortier, Chief of the Division of Irrigation Investigations, planned and carried out the work during the years 1916 and 1917. Mr. Cone resigned to enter private practice in February, 1918, and Ralph L. Parshall succeeded him as the representative of the bureau in Colorado. Since the writer, however, had been intimately connected with the investigation from the beginning, it fell to his lot to complete the work and write the report.

CACHE LA POUDRE VALLEY.

The Cache la Poudre River drains an area of approximately 1,900 square miles in north-central Colorado. The main stream heads in Chambers Lake, a few miles east of the crest of the Medicine Bow Range, and flows in a fairly straight line to its junction with the South Platte River, 60 miles southeast. With its tributaries it drains slopes of the Laramie, Medicine Bow, and Snowy Mountains. About 30 miles east of Chambers Lake the river breaks through the last line of foothills and flows out on the plains. This line of foothills forms a natural division and breaks the basin into two distinct parts. West of the foothills the country is all rough and mountainous and lies at an altitude of from 6,000 to 14,000 feet. Irrigation in this section of the basin is confined almost entirely to forage crops in narrow strips along the streams. East of the foothills the valley proper rarely exceeds a mile or two in width and is 50 to 100 feet below the level of the adjacent land. In this section, and south of the river, the bluffs are rather abrupt and are only a short distance from the divide between the Cache la Poudre and Big Thompson basins, thus limiting irrigation to the river bottoms and a small area of bench land southwest of Fort Collins.

North of the river a rolling prairie, rising gradually from the first bench, extends northward to the Wyoming line, and in this section are located the larger canals and at least 80 per cent of the irrigated land in the basin. The altitude of the eastern division of the basin ranges from 4,500 to 5,500 feet.

In 1870 occurred two events of great importance in the development of the valley. The first was the completion of the Denver Pacific Railroad from Cheyenne to Denver, which afforded a safe and quick means of travel from the East and solved, to a great extent, the problem of supplies. The second was the establishment of the Union Colony in the vicinity of the present town of Greeley.

The first work of this colony was the construction of the Greeley Canal No. 3 to water the town site and the lands adjoining.[1] In the fall of 1870 work on the Greeley Canal No. 2 was started, and water was carried in the canal the following spring. The Greeley Canal No. 2 is notable for the fact that it is the first large canal built by community effort in Colorado and also the first built to water extensive areas of bench land. Mistakes were made in the design and construction of these canals and the cost was many times the estimated amount, but the colonists kept fighting against disheartening odds and were finally rewarded by success.

The success of the Greeley colony in canal building was such that construction by corporations or community effort soon almost entirely supplanted individual effort, and by 1882 practically all the large canals of the valley had been built. Since 1882 the development has consisted of extensions of canals already constructed, the construction of ditches to bring water across from other drainage basins, and the building of the reservoir systems of the valley made necessary by the diversification of crops to include those requiring late irrigation.

METEOROLOGY.

Meteorological records have been taken at the State Agricultural College at Fort Collins for many years and are complete beginning with 1887. (Fig. 1.) While there is a slight variation in climatic conditions over the valley proper, due to a gradual transition from a plains to a foothill climate, this difference is so small as to be of no significance so far as irrigation is concerned, and the Fort Collins records may be taken as representative of the whole valley. They show the chief characteristics of the climate to be a light rainfall, with correspondingly few stormy days and much sunshine, a wide range in daily and seasonal temperature, low relative humidity, a moderately high wind movement, and a comparatively low rate of evaporation. In Table 1 is given a summary of 31 years of the Fort Collins records.

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[1] See Second Biennial Report, State Engineer of Colorado, 1883–84, by Col. E. S. Nettleton. Also History of Greeley and the Union Colony, by David Boyd. Also History of Larimer County, by Ansel Watrous. Also University of Colorado Historical Collections: The Union Colony at Greeley, 1869–1871, by James F. Willard.

TABLE 1.—*Summary of meteorological records at Fort Collins, Colo., 1887–1917.*[a]

Month.	Rainfall (inches).			Temperature (°F.).			Wind (miles per hour).			Relative humidity (per cent saturation), mean.	Evaporation (inches).[b]		
	Mean.	Monthly mean. Maximum.	Monthly mean. Minimum.	Mean.	Absolute maximum.	Absolute minimum.	Mean.	Monthly mean. Maximum.	Monthly mean. Minimum.		Mean.	Maximum monthly mean.	Minimum monthly mean.
January	0.35	2.32	0.01	25.9	71.0	−31.4	6.4	10.1	4.0	71.3	1.23	2.64	0.68
February	.62	1.65	.03	26.7	70.0	−38.4	6.9	10.4	4.4	72.5	1.45	3.23	.58
March	1.05	3.35	.00	35.7	80.3	−24.6	7.9	11.9	4.7	67.1	2.63	4.60	.57
April	2.16	10.56	.05	46.1	91.0	5.1	8.4	12.3	5.9	59.7	4.21	6.17	2.24
May	3.06	7.47	.60	53.9	90.0	12.1	6.9	10.9	4.7	63.4	4.68	6.63	3.49
June	1.48	3.65	.03	63.1	94.2	31.2	6.0	9.6	4.5	63.9	5.42	7.70	3.97
July	1.82	4.95	.17	68.1	99.9	36.0	4.8	7.0	3.1	66.8	5.59	7.32	4.26
August	1.23	3.14	.16	67.2	99.6	31.7	4.7	6.4	3.1	67.2	5.07	6.57	3.79
September	1.29	3.08	.00	59.2	95.0	22.0	5.1	7.2	3.5	67.2	4.30	5.57	3.14
October	1.12	3.23	......	47.7	88.0	− 8.0	5.7	9.1	3.3	67.9	3.28	4.64	2.17
November	.40	1.80	......	36.0	78.0	−21.1	6.0	9.4	2.8	69.8	1.56	2.81	.62
December	.46	4.08	......	28.0	68.0	−31.0	6.5	10.2	3.4	72.3	1.17	1.88	.26
Year	15.04	22.49	7.11	46.5	99.9	−38.4	6.3	9.3	4.7	67.4	40.59	47.30	34.24

[a] All meteorological records pertaining to Fort Collins were taken from Colorado Experiment Station Bulletin No. 245. Colorado Climatology, by Robert E. Trimble, 1918.
[b] From tanks 3 by 3 feet deep. Water surface about 2 inches above ground.

Approximately two-thirds of the rainfall comes during the growing season, from April 15 to September 15. An average of 74 days of the year shows precipitation, mostly in the form of light showers and snows, though rains of more than 0.5 inch usually occur several times during the season. Heavy local rains or cloudbursts occasionally do some damage to crops and canals, but in general they are rather a benefit, as they flood the streams and afford additional water for irrigation and storage. At Greely[2] the average rainfall is about 2 inches less than at Fort Collins, but the seasonal distribution is about the same. In the mountainous section of the Cache la Poudre drainage area the rainfall is heavier and averages perhaps 22 inches annually. There is a rather notable range of temperature in the valley. At Greeley temperatures of 103° above and 45° below zero have been recorded, giving an absolute range at that point of 148°. At Fort Collins the mean temperatures for January and for July differ by 40°, and the daily range is approximately 30°, but warm chinooks from the west or cold waves from the north often produce a change of as much as 40° within 2 or 3 hours. In general, the extremes of temperature last only a short time, and the impression of the climate which remains is one of crisp dry air, clear skies, and warm sunlight. At Fort Collins the average period between killing frosts is 144 days,

[1] Meteorological records for Greeley were furnished by F. H. Brandenburgm, U. S. Weather Bureau, Denver.

or from May 5 to September 26, while at Greeley the period is 9 days longer, from May 1 to October 1.

In spite of low relative humidity and moderately high wind movement, the average annual evaporation from a water surface is comparatively low at Fort Collins. The average for the year is reduced by the small amount for the winter months. During the summer months, when water is held in reservoirs for future irrigation, the evaporation is heavy.

Weather conditions during the period of investigation varied from the average only to a small extent. Figure 1 is given to show the rainfall, temperature, and evaporation at Fort Collins during 1916 and 1917 as compared with the average for a period of 31 years.

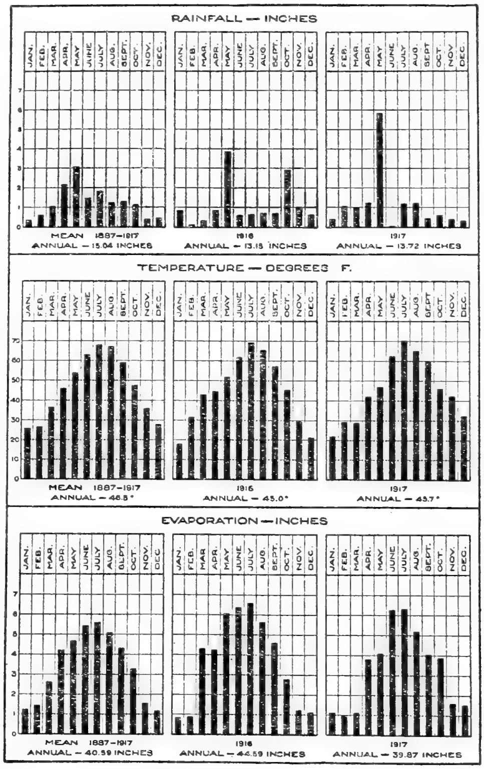

FIG. 1.—Meteorological conditions at Fort Collins during the period of the investigation compared to the average for 31 years.

SOILS.[3]

A soil survey including the Cache la Poudre Valley was made in 1904 by the Bureau of Soils, United States Department of Agriculture, and 10 soil types were found and mapped. Those occurring most extensively in the valley were designated as Colorado fine sandy loam, Laurel sandy loam, and Fort Collins loam.

The Colorado fine sandy loam covers a large area north of the river between Fort Collins and Greeley. It is a residual soil, light to dark brown in color, extends to an average depth of about 3 feet, and is underlain by a loam or a heavy fine sandy loam to a depth of 6 feet or more. The silt and clay content increases with the depth. The loose texture of this soil affords good drainage and, except in draws or depressions where seepage comes to the surface, there is

[3] Soil Survey of the Greeley Area, Colorado, by J. Garnett Holmes and N. P. Neill. Field Operations of the Bureau of Soils, 1904.

not enough alkali to injure crops. This soil is especially well adapted to grain, alfalfa, and potatoes.

The Laurel sandy loam is an alluvial soil and occurs in a strip one-half to 1 mile wide in the river bottoms. It ranges in depth from 2 to 5 feet, and is dark brown to black in color. The soil becomes more sandy with depth, passing gradually into coarse sand and water-worn gravel. This soil is not very well drained and the water table is near the surface the greater part of the year. Only small areas, however, are affected by alkali. This soil is particularly well adapted to cabbages, onions, and sugar beets.

The Fort Collins loam occurs in small areas north of Greeley and in the vicinity of Fort Collins. It consists of a reddish to a very dark brown light loam, from 4 inches to 1 foot in thickness, underlain by a layer of heavy loam from 1 to 4 feet in thickness. Below this layer of loam the subsoil grades again into a light loam extending to a depth of 6 feet or more. The soil is very sticky when wet and bakes badly. It is fairly well drained, is affected by alkali in small areas only, and is adapted to fruits, grain, potatoes, alfalfa, and sugar beets.

WATER RESOURCES.

Water for irrigation in the Cache la Poudre Valley is obtained from the river and its tributaries; from supply ditches collecting run-off from the high slopes of the drainage systems of the Grand, Michigan, and Laramie Rivers; from shallow pumped wells; and from seepage from canals, reservoirs, and irrigated lands which returns to the river or its tributary channels.

A station for gaging the river has been maintained since 1884 at the mouth of the canyon, above all canal headings but the North Poudre and Poudre Valley, and because of the permanence of the channel section there the continuous automatic record of stage, the frequent ratings to check the discharge curve, and the length of the period covered, the records of discharge at that point are particularly complete and accurate. As the river is fed principally by melting snow, characteristic marked variations in yearly, seasonal, and daily discharge are to be expected.

The discharge varies from year to year with the fall and winter temperatures and the amount of precipitation on the upper slopes of the basin, the greatest discharge coming after a fall and winter which pack the deep gulches with snow and ice. The annual discharge at the canyon station averages 320,000 acre-feet, but has varied from a minimum of 169,000 acre-feet in 1888 to a maximum of 689,000 acre-feet in 1884.

The wide seasonal variation is due to the spring flood produced by rapid melting of snow in the hills. Its duration and intensity depend on the amount of snow to be melted and the temperature, a continued high temperature producing a rapid rise, a high crest early in the season, and a subsequent rapid fall, and a low temperature producing a more gradual rise and fall with comparatively low and late crest. The average date of the crest is June 10, but it has come as early as May 17 and as late as June 28. The discharge at the crest has varied from a mean of 1,550 second-feet on June 19, 1888, to a mean of 5,800 second-feet on June 23, 1917. The lowest discharge is about 30 second-feet and occurs in winter after severe cold weather has frozen most of the stream.

The daily rise and fall is pronounced only during the spring flood, when alternate freezing and thawing of snow on the high slopes of the basin produce a variation of several hundred second-feet at the gaging station, the maximum recorded being 1,500 second-feet. Sudden floods, due to storms, are common and there are records showing a rise of more than 5 feet in less than 30 minutes, caused by cloudbursts in narrow branch canyons with steep slopes.

Records of discharge of the river from 1884 to 1917, inclusive, are given in Table 2. During the winter months ice conditions at the gaging station are such that automatic records are of little value, and such as were available were discarded. Estimates of the flow from November to March, inclusive, were furnished by John Armstrong, water commissioner for the stream, who has handled the division of the winter flow for over 25 years. To arrive at the annual discharge, Mr. Armstrong's estimates for the winter months were combined with available figures for other months, and then, if April or October records were partly missing, they were interpolated in the proportion of the percentages shown in the table. The winter flow is so small that this method of estimating could not produce an error of as much as 5 per cent. Data included in the table are from the original records of the Colorado Experiment Station and from reports of the State engineer. In considering this table it should be noted that the North Poudre and Poudre Valley Canals divert about 40,000 acre-feet above the gaging station annually, and that part of the water passing the station is foreign water from other drainage basins.

TABLE 2.—*Discharge of the Cache la Poudre River at gaging station at mouth of canyon.*

Year.	Discharge in second-feet.												Estimated annual discharge in acre-feet.
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
1884				219	2,536	4,812	2,143	792	305				689,000
1885					1,419	2,910	1,860	657	272				478,000
1886					1,309	1,872	717	306	185				302,000
1887						1,802	737	310	174				
1888					489	1,117	421	201	105				169,000
1889				113	770	1,339	511	184	69	70			203,000
1890				200	1,046	1,281	647	290	103	81			271,000
1891				144	1,250	1,833	541	228	138	118			275,000
1892					408	1,512	735	209					
1893					570	1,802	614	237					
1894					1,406	2,063	735	339	164	104			321,000
1895					1,191	2,346	1,222	499	220	175			374,000
1896					912	1,062	452	274	294	199			219,000
1897					1,960	1,728	511	379	166	123			303,000
1898				146	656	1,317	485	154	70	61			192,000
1899					1,206	2,609	1,452	563	216	156			408,000
1900				742	3,095	3,281	674	231	134	108			518,000
1901					1,802	2,049	774		135	99			
1902				106	1,069	1,291	379	176	166	136			219,000
1903					801	2,715	964	282	164	156			337,000
1904				161			1,043	328	176				
1905				317	1,031	2,707	908	340	158				356,000
1906					1,083	1,652	935						
1907				119	646	2,777	1,757	473	186				388,000
1908				135		1,493	792	766	229				
1909				239	703	3,703	1,852	452	331	140			466,000
1910				179	780	947	269	128	152	154			176,000
1911				69	819	1,707	764	218	173	126			252,000
1912				63	785	2,186	1,230	429	212	163			325,000
1913					920	1,230	538	265	204	184			229,000
1914				215	2,147	2,500	818	335	195	91			400,000
1915					591	1,521	700	274	208	116			232,000
1916				151	847	1,703	754	397	263	114			274,000
1917				134	1,295	3,996	2,050	392	292	111			518,000
Average discharge, sec.-ft.[1]	50	55	55	192	1,147	2,087	911	347	189	127	83	60	320,000
Equivalent discharge, acre-feet	3,070	3,050	3,375	11,405	70,405	123,970	55,920	21,300	11,225	7,795	4,930	3,685	320,130
Per cent	1.0	0.9	1.1	3.6	22.0	38.7	17.5	6.7	3.5	2.4	1.5	1.1	100.0

[1] The figures in this line are not averages of the preceding figures but were obtained by combining the daily averages for each month. By this method records for only a part of a month which could not be shown as a monthly average could be included in the general average.

Figure 2 shows the discharge of the river from April to September, inclusive, during 1916 and 1917, the period of the investigation, as compared with the average for a period of 34 years. It will be noticed that the discharge for 1916 was very nearly normal, but that for 1917 was far above normal.

The small creeks tributary to the Cache la Poudre River below the canyon furnish only a small percentage of the total water supply of the valley. Rainstorms flood these creeks for a day or two, but ordinarily they are dry or nearly so, except where a flow of a few second-feet is produced by seepage. Records of flow of the more important of these tributaries, together with estimates for the smaller streams, show that the supply from this source is about 40,000 acre-feet in average years, of which 15,000 acre-feet may be classed as

normal run-off and 25,000 acre-feet as returned seepage. The greater part of this flow is intercepted by canals and reservoirs before it reaches the river.

The foreign water turned into the Cache la Poudre River has averaged 35,000 acre-feet for a number of years. The Grand River ditches of the Water Supply & Storage Co. bring over about 11,500 acre-feet from the Grand River drainage area. Ditches of the Water Supply & Storage Co. and the North Poudre Irrigation Co. draw about 3,500 acre-feet from the Michigan River drainage area. The remainder, 20,000 acre-feet, is brought over from the Laramie River drainage area by the Skyline Ditch of the Water Supply & Storage Co., the Greeley-Poudre irrigation district's tunnel, the Sand Creek feeder of the Worster Reservoir, and others. The greater part of this foreign water is diverted by the North Poudre Valley, and the Larimer County Canals. The Greeley-Poudre district, having no land under irrigation, usually sells the tunnel water to the highest bidder. The record of discharge of the river at the canyon rating station includes all foreign water passing that point.

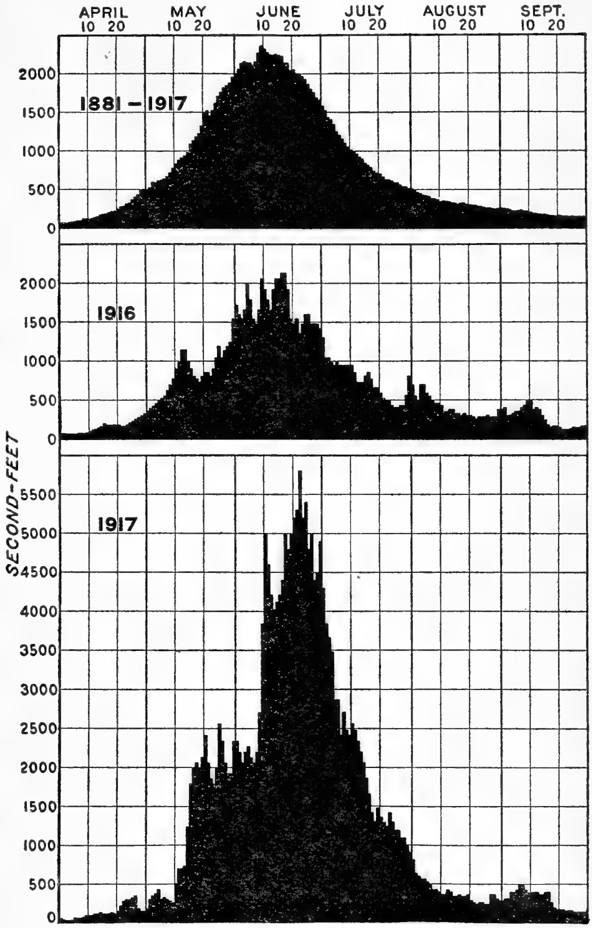

FIG. 2.—Discharge of the Cache la Poudre River at the rating station at the mouth of the canyon during the period of the investigation compared with the average for approximately 35 years.

The amount of water obtained by pumping from wells does not exceed 5,000 acre-feet annually and is generally used late in the

season instead of reservoir water to provide for an irrigation after canal supplies fail.

The total amount of seepage return to the river, exclusive of that coming through regular channels, is about 110,000 acre-feet annually. During the winter months only the return above the intake of the Cache la Poudre Reservoir may be used, and this is estimated to be about 8,000 acre-feet. During the summer months canals on the lower reaches of the river depend to a considerable extent on this return flow to satisfy their rights, and it is estimated that during these months 51,000 acre-feet are available for their use. Combined, the total available flow for the year is 59,000 acre-feet.

To summarize, the water supply of the valley includes a normal run-off of 340,000 acre-feet in the river and its tributaries, 35,000 acre-feet of foreign water, 5,000 acre-feet pumped from wells, and available seepage to the amount of 84,000 acre-feet, a total supply of 464,000 acre-feet. This supply in the course of time will be increased slightly by pumping and by a greater return of seepage, but any material increase seems improbable.

With the exception of very short periods during high floods, the entire available flow of the stream is taken on rights which have been in existence for years. There is an occasional surplus subject to storage, but because of the uncertainty attaching to it and the probable high cost of developing it, the feasibility of such a supply is highly questionable. The demand on the river in June the month of maximum flow, is close to 120,000 acre-feet,[4] which is equivalent to an average flow of approximately 2,100 second-feet. From Table 2 it appears that the river has failed to reach that discharge in 18 of the 33 years covered by the records. To produce a surplus of 20,000 to 25,000 acre-feet a discharge of at least 2,500 second-feet would be required during June, and such a discharge occurred in only 9 of the 33 years covered by the records. From this it is clear than any further storage projects would have to depend on a surplus which would be of considerable size only about once in 3 or 4 years. The amount available annually for use from such a supply would be very small and very costly.

SEEPAGE RETURN.

One of the questions of particular interest now in many irrigated valleys is that of seepage return to streams. It is a well-known fact that, with the extension of irrigation, this return has so increased that canals on the lower reaches of the rivers, which once suffered seriously because their rights would not be satisfied, are now plentifully supplied with water. In the Cache la Poudre Valley the effect of the seepage return is very marked. Late in the season it is often the case that the river is dry in several places, yet a number of

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[4] See Tables 7 and 8.

the lower canals may be drawing their full appropriations from the supply developed by seepage return.

Prof. L. G. Carpenter, for a number of years director of the Colorado Experiment Station, made one or more measurements of the Cache la Poudre River each year, for more than 20 years, to determine the seepage return to the stream. These determinations were spot measurements, good only for the conditions at the time of the observation, but the large number of observations and the care with which they were made establishes their dependability. The average of the measurements, made in the spring and fall at low stages of the river, shows a return between the canyon and the mouth of the river of 153 second-feet, which included seepage intercepted by canals near the river.

The rating stations maintained during 1916 and 1917 on the river, its tributaries, and the canals diverting from it, provided continuous records from which the seepage return shown in Table 3 was determined. These figures show the net return to the river from the canyon to the mouth, but do not include seepage entering through the channels of the various tributaries below the canyon. To arrive at these figures the total supply from all sources was determined by adding the discharge of the river at the lower rating station and the discharge of all canals, less the water returned to the river through sluices and wasteways. The supply available from the normal flow of the stream was then obtained by adding the discharges of the North Poudre and Poudre Valley Canals, the river discharge at the canyon station, and the inflow to the river from the tributaries entering below the canyon. The supply available from the normal flow of the stream was then subtracted from the total supply, the difference being the amount of seepage return. Results obtained in this manner will contain a certain amount of run-off from rains and irrigation which reaches the river directly instead of passing through the tributary channels on which measurements were made. The amount is small, however, and may be neglected.

TABLE 3.—*Seepage return to the Cache la Poudre River in 1916 and 1917.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Return in 1916 (acre-feet)	4,600	4,150	4,667	6,297	11,328	9,491	13,801	13,324	10,233	11,412	10,615	7,465	....
Return in 1917 (acre-feet)	6,604	6,094	7,875	7,727	(1)	(1)	14,534	14,322	9,830	8,586	10,186	6,386	....
Average in acre-feet	5,602	5,122	6,271	7,012	11,328	9,491	14,167	13,823	10,032	9,999	10,400	6,925	110,172
Average in second-feet	91	92	102	118	184	160	231	225	169	163	175	113	152

[1] The figures for May and June, 1917, are omitted on account of their probable inaccuracy. Records at the station near the mouth of the river were interrupted for a week or ten day when the discharge was over 2,000 second-feet. Results obtained by interpolation are subject to too great an error at that stage of the river.

Seepage which reaches the tributaries and then flows into the river is approximately 15,000 acre-feet yearly. There are many other streams of seepage and runoff from irrigated fields which are

intercepted for direct use or for storage. A conservative estimate of the amount of this seepage would be 12,000 acre-feet. Added together, these give a total seepage return for the valley of approximately 137,000 acre-feet annually, which is equivalent to a constant flow of 190 second-feet. The average annual water supply of the valley, exclusive of seepage, is 380,000 acre-feet, and the seepage return as estimated above is slightly over 36 per cent of that supply.[5]

DRAINAGE CONDITIONS.

From the preceding section on seepage return the natural presumption would be that drainage must be one of the important problems of the valley, but such is not the case. As is to be expected in any irrigated area, for many years wet spots have developed, but these spots rarely exceeded 40 to 80 acres in extent and were usually drained as soon as the condition became bad. Because of the rolling topography, the sandy character of the soil, and the many natural channels, the construction of the required small systems of tile drains presented no difficulties. It is estimated that close to 10 per cent of the irrigated land of the valley is underlain by drains. Land needing drainage at present is in scattered spots and in only two instances is there as much as 500 acres in one body.

EXCHANGE OF WATER.

In order to utilize sites which could be developed cheaply and at the same time to save the cost of intake canals, 12 reservoirs of the Cache la Poudre Valley, with an aggregate capacity of about 50,000 acre-feet, were built below the distributing canals of the companies owning them. The problem of making the water stored in these reservoirs available for use in the distributing canals above has been solved by the development of a very complicated system of exchange of water. In 1916, an average year, the operation of the exchange system made available for use on higher land about 55,000 acre-feet of water stored in low reservoirs, or 14 per cent of the total supply used by all the canals of the valley.

The principal exchange system of the valley involves the 4 largest canals, and to understand it clearly a few facts must be kept in mind. Beginning at the lower end of the river and going upstream, the Greeley Canal No. 2, the Larimer and Weld Canal, and the Larimer County Canal of the Water Supply & Storage Co. head in the order named. Next above and diverting from the North Fork is the North Poudre Canal. The principal water rights of these canals stand in the same order of priority, the Greeley Canal No. 2 coming first with an appropriation dating 1870 and the North Poudre Canal coming last with an appropriation dating 1881. Reservoirs No. 5 and No. 6 of the North Poudre Co. are too low to supply directly any land under the canal, and their outlet empties into the Larimer County

[5] This does not include seepage from Poudre Valley land entering directly into the South Platte.

Canal. With the exception of Black Hollow, the reservoirs of the Water Supply & Storage Co. below the canyon are also low and their outlets are arranged so that water from them may be turned into the Larimer and Weld Canal or the river. Below the Larimer and Weld Canal is the Windsor Reservoir, which has a capacity of 17,000 acre-feet and discharges into the Greeley Canal No. 2. A few of the rights in this reservoir are held under the Greeley Canal No. 2, but the great majority are owned by farmers under the Larimer and Weld Canal. The exchange is operated by taking advantage of all these conditions.

Except during high-flood periods the rights of the Greeley Canal No. 2 may entitle it to practically the entire flow of the North Fork, but instead of allowing this water to flow down the channel of the river to be taken directly by the canal, the water commissioner permits the North Poudre Canal to divert it for use, and directs that an equal amount be turned from the Windsor Reservoir to the Greeley Canal No. 2 when the drop in the river reaches that canal. If, for instance, a flow of 100 second-feet has been taken for 10 days, the North Poudre Co. then owes the Windsor Reservoir 1,985 acre-feet, or 87,000,000 cubic feet, as it is expressed locally, and to secure the debt that amount of water is held in the North Poudre Reservoir No. 6. In other words, Windsor Reservoir water to the amount of 1,985 acre-feet has been transferred upstream for delivery to rights under the Larimer and Weld Canal, and the North Poudre Co. has been able to use in its main canal 1,985 acre-feet of the water stored in its low reservoirs. While channels are available through which the water in Reservoir No. 6 could be delivered direct to the Larimer and Weld Canal, this is never done. Instead, the water is delivered to the Larimer County Canal Co. at any time on demand of the Water Supply & Storage Co., and in exchange this company holds sufficient water in its low reservoirs to deliver 1,985 acre-feet to the Larimer and Weld Canal to supply the demands of the holders of Windsor Reservoir rights. It will be noted that while the Greeley Canal No. 2 has been left undisturbed in its rights, the use of 1,985 acre-feet of its appropriation has served to exchange nearly 6,000 acre-feet of water stored in low reservoirs.

WATER RIGHTS.

The development of irrigation was so rapid in the Cache la Poudre basin that the problem of an equitable division of the water in the stream arose earlier than in any other section of the State. The need became pressing with the construction of large canals in the late seventies, and the efforts of the people of the valley to solve the problem resulted in the inauguration in 1879–1881 of the present system of water administration. The first general adjudication of water rights in the Cache la Poudre and its tributaries was held immediately after, and with few exceptions the rights decreed then

are now in force and unimpaired. In Table 4 the rights of the principal canals of the valley are listed, with notes to show how they were acquired or changed. Ninety per cent of the direct irrigation rights of the stream are included, those omitted being chiefly rights of small ditches above the canyon or at the head of tributaries entering below the canyon.

TABLE 4.—*Water rights of the principal canals of the Cache la Poudre Valley.*

	Priority number.	Date.	Amount (sec.-ft.).	Remarks.
North Poudre Canal	2	June 1, 1861	0.72	Transferred from Watrous, Whedbee & Secord Ditch.
	17	Apr. 15, 1866	4.77	Transferred from Taylor and Gill Ditch.
	19	July 1, 1866	2.16	Transferred from Watrous, Whedbee & Secord Ditch.
	29	June 1, 1868	2.16	Do.
	40	May 1, 1871	4.00	Transferred from Wm. Calloway Ditch No. 1; use limited to certain land.
	52	July 20, 1872	15.00	Transferred from Arthur Ditch.
	60	July 1, 1873	7.20	Transferred from Aquila Morgan Ditch.
	[1] 61	do	9.38	Transferred from Brown Ditch No. 1.
	63	Aug. 15, 1873	3.32	Transferred from Brown Ditch No. 2.
	66	Sept. 1, 1873	11.00	Transferred from Arthur Ditch.
	69	May 15, 1874	3.32	Transferred from Brown Ditch No. 3.
	77	May 1, 1875	6.72	Transferred from Brown Ditch No. 4.
	79	Jan. 1, 1876	6.72	Transferred from Brown Ditch No. 5.
	80	June 1, 1876	6.72	Transferred from Brown Ditch No. 6.
	82	June 1, 1877	2.85	Transferred from Brown Ditch No. 7.
	97	Feb. 1, 1880	315.00	Original appropriation: by court decree subsequently made inferior to priority No. 100 of the Larimer County Canal.
Total			401.04	
Poudre Valley Canal	28	Mar. 15, 1868	1.63	Transferred from Canyon Ditch.
	56	Mar. 20, 1873	24.44	Do.
Total			26.07	
Pleasant Valley and Lake Canal.	4	Sept. 1, 1861	10.97	Original appropriation.
	11	June 10, 1864	29.63	
	51	July 10, 1872	16.50	
	92	Aug. 18, 1879	80.83	
Total			137.93	
Larimer County Canal	5	Mar. 1, 1862	10.77	Transferred from Pioneer Ditch.
	12	Sept. 15, 1864	13.89	Do.
	28	Mar. 15, 1868	4.66	Transferred from Canyon Ditch.
	56	Mar. 20, 1873	4.00	Do.
	84	Apr. 1, 1878	7.23	Appropriation of Smith Ditch acquired with right of way.
	100	Apr. 25, 1881	463.00	Original appropriation; by court decree subsequently made superior to priority No. 97 of the North Poudre Canal.
Total			503.55	
Jackson Ditch	3	June 10, 1861	11.67	Original appropriation.
	36	Oct. 21, 1870	14.42	
	67	Sept. 15, 1873	12.13	
	91	July 15, 1879	12.70	
Total			50.92	
Little Cache la Poudre Ditch.	31	May 1, 1869	62.08	Do.
	58	May 1, 1873	20.42	
Total			82.50	
Taylor and Gill Ditch	17	Apr. 15, 1866	12.15	Of the original appropriation of 18.48 second-feet, 4.77 second-feet transferred to North Poudre Canal and 1.56 second-feet returned to river to protect it from loss on account of transfer.
Larimer County Canal No. 2.	14	May 1, 1865	4.00	Transferred from John R. Brown Ditch.
	57	Apr. 1, 1873	175.00	Original appropriation.
Total			179.00	

[1] The appropriations of the Brown Ditches are not owned by the company but are carried in the canal under a perpetual contract.

TABLE 4.—*Water rights of the principal canals of the Cache la Poudre Valley*—Continued.

	Priority number.	Date.	Amount (sec.-ft.).	Remarks.
New Mercer Canal	25	Oct. 1, 1867	7.03	Transferred from Josh Ames Ditch (in litigation).
	33	Sept. 1, 1869	4.17	Original appropriation.
	47	Oct. 10, 1871	8.33	
	49	July 1, 1872	15.00	
	99	Feb. 15, 1880	136.00	
Total			170.53	
Arthur Ditch	2	June 1, 1861	.72	Transferred from Watrous, Whedbee & Secord Ditch.
	19	July 1, 1866	2.16	Do.
	29	June 1, 1868	2.16	Do.
	32	June 1, 1869	1.67	Original appropriation.
	38	Apr. 1, 1871	31.67	
	52	July 20, 1872	18.33	Remainder of appropriation of 33.33 second-feet transferred to North Poudre Canal.
	66	Sept. 1, 1873	52.28	Remainder of appropriation of 63.28 second-feet transferred to North Poudre Canal.
Total			108.99	
Larimer and Weld Canal	10	June 1, 1864	3.00	Original appropriation of No. 10 ditch.
	21	Apr. 1, 1867	16.67	
	45	Sept. 20, 1871	75.00	
	73	Jan. 15, 1875	54.33	
	88	Sept. —, 1878	571.00	Original appropriation of Larimer and Weld Canal.
Total			720.00	
Josh Ames Ditch	25	Oct. 1, 1867	17.97	Remainder of appropriation of 35.92 second-feet returned to river by courts or transferred (in litigation).
Lake Canal	54	Nov. 1, 1872	158.35	Original appropriation.
Coy Ditch	13	Apr. 10, 1865	31.63	Do.
Chaffee Ditch	48	Mar. 10, 1872	22.38	Do.
Boxelder Ditch	15	Mar. 1, 1866	32.50	Do.
	23	May 25, 1867	8.33	
	30	July 1, 1868	11.93	
Total			52.76	
Greeley Canal No. 2	37	Oct. 25, 1870	110.00	Do.
	44	Sept. 15, 1871	170.00	
	72	Nov. 10, 1874	184.00	
	83	Sept. 15, 1877	121.00	
Total			585.00	
Whitney Ditch	7	Sept. 1, 1862	48.23	Do.
	43	Sept. 10, 1871	12.95	
Total			61.18	
B. H. Eaton Ditch	9	Apr. 1, 1864	29.10	Do.
	18	June 1, 1866	3.33	
	53	July 25, 1872	9.27	
Total			41.70	
Jones Ditch	24	Sept. 1, 1867	15.52	Do.
Greeley Canal No. 3	35	Apr. 1, 1870	52.00	Do.
	46	Oct. 1, 1871	41.00	
	50	July 15, 1872	63.13	
	59	May 15, 1873	16.66	
Total			172.79	
Boyd and Freeman Ditch	6	Mar. 15, 1862	66.05	Do.
	20	July 15, 1866	9.00	
	62	Aug. 1, 1873	24.23	
Total			99.28	
Ogilvy Ditch		July 21, 1881	57.60	Original appropriation; junior to all rights of the first adjudication.

The court, in arriving at the decree of 1882, had little definite information regarding the water requirements of various soils and crops to guide it, nor were there available any accurate measurements of the capacities of the canals, whose rights were being adjudicated; and it was human for the claimants to give themselves the benefit of the doubt. The result was that many of the canals were given decrees for appropriations in excess of their capacities or of their requirements for years to come. Enlargement and extension of the area irrigated by most of these canals have brought them to the point where their capacities, amounts diverted, and amounts used are well balanced. In the case of others no enlargement has taken place, but part of the excess appropriation has been transferred to other canals. Still others retain their excessive rights, but have insufficient capacity to carry them or else serve such a small acreage that only a part of the appropriation can be used properly.

In Table 5 a comparison is made between the total rights of each canal and its capacity, as shown by its maximum discharge during 1916 and 1917. The maximum discharges noted, which covered periods of at least two hours, are believed to represent with fair accuracy the maximum capacities of the canals. The fact that records were being taken by disinterested agencies seemed to appeal to some canal men as affording an opportunity of establishing a record of the capacity of their canals. In 1917 a number were crowded to their limit for short or long periods when the water might more profitably have been allowed to pass on down the river. In 1916 conditions were different and maximum discharges were carried that year because the water was actually needed. If the Poudre Valley Canal be omitted, which is warranted by the fact that its capacity is primarily for carrying water for storage, the canals show an average capacity nearly 10 per cent in excess of their rights.

TABLE 5.—*Comparison between water rights and capacities of canals of the Cache la Poudre Valley.*

	Total rights (second-feet).	Maximum discharge (second-feet).	Ratio (per cent.)		Total rights (second-feet).	Maximum discharge (second-feet).	Ratio (per cent.)
North Poudre Canal	401	201	50	Larimer and Weld Canal	720	754	105
Poudre Valley Canal	26	297	1,142	Josh Ames Ditch	18	[1] 20	111
Pleasant Valley and Lake Canal	138	157	114	Lake Canal	158	185	117
				Coy Ditch	32	[1] 18	56
Larimer County Canal	504	597	118	Chaffee Ditch	22	[1] 21	95
Jackson Ditch	51	52	102	Boxelder Ditch	53	121	228
Little Cache la Poudre Ditch	82	137	167	Greeley Canal No. 2	585	558	95
				Whitney Ditch	61	61	100
Taylor and Gill Ditch	12	22	183	B. H. Eaton Ditch	42	[1] 23	55
Larimer County Canal No. 2	179	186	104	Jones Ditch	16	[1] 29	181
				Greeley Canal No. 3	173	102	59
New Mercer Canal	171	112	65	Boyd and Freeman Ditch	99	[1] 24	24
Arthur Ditch	109	51	47	Ogilvy Ditch	58	122	210

[1] These figures are based on daily gage readings. The remainder are from continuous automatic records of gage heights.

So many varying factors determine the time any right may draw from the river that it is impossible to make any statement in this regard which will not be inaccurate under certain combinations of circumstances. It is generally true, however, that appropriations up to and including priority No. 25 are satisfied throughout the season, while the original appropriations of the Larimer County and North Poudre Canals, priorities No. 100 and No. 97, draw only from 1 to 3 weeks during June. Between these two extremes are a large number of appropriations which fail chiefly in August. Several conditions tend to increase the length of time the later appropriations may draw. Usually there is plenty of rain in the early spring to get the crops started and the older appropriators call for their water only when it is really needed, thus permitting the later rights to draw the available supply. Later in the season some of the oldest appropriators may cut back to the river a part of their supply, or it may be taken in at the head but wasted back to the river through lower wasteways. When the Pleasant Valley and Lake Canal has an excess of 10 to 20 second-feet which it will not need for 24 hours it is usually cut back to the river at the Bingham Hill waste, though it might be carried on through the canal and tailed into Fossil Creek to reach the river again through the outlet of Fossil Creek Reservoir. The return water of the stream is of great importance in stretching the period during which the later rights may draw. During the summer this return is sufficient to supply a considerable part of the demand below the Larimer and Weld Canal, which permits a corresponding amount to be drawn from the river by later rights above. This return is of especial benefit to the Ogilvy Ditch, which is the lowest on the river. Its right is junior to practically every other right on the river, but the return water to the stream affords it a sufficient supply for the greater part of the season in average years.

The year 1916 was nearly normal and the dates on which the various rights failed that year may be assumed to be close to the average. Ordinarily it would be expected that on a small stream like the Cache la Poudre the flow of the stream at the head of the irrigated area would bear some close relation to the aggregate of the rights prior to the right cut-off, but this does not hold true. The return of seepage, water wasted back from canals, foreign water carried, exchange water turned into the river, low demand, and excessive decrees all upset any calculation along this line. The appropriation of the Larimer County Canal, priority No. 100, was cut on June 29 when the river at the canyon station was carrying approximately 1,480 second-feet. The rights senior to the right of the Larimer County Canal aggregate 3,600 second-feet.

On July 6 the appropriation of the Larimer County Canal No. 2, priority No. 57, was cut when the river was carrying approximately 1,000 second-feet. Rights prior to this appropriation aggregate 1,800 second feet. On August 1 the appropriation of the Lake Canal, priority No. 54, was cut when the river was carrying approximately 700 second-feet. Rights prior to this appropriation aggregate 1,600 second feet. On August 17 the Greeley Canal No. 2 was cut when the river was carrying 325 second-feet. The priority number of the first right is 37 and prior rights aggregate approximately 700 second-feet. On August 23 the Josh Ames Ditch, priority No. 25, was cut when the river was carrying 250 second-feet. Prior rights aggregate 500 second-feet.

From the preceding list of rights it will be noted that there have been many transfers of appropriations from one canal to another. Whether these transfers are of benefit or harmful to a community depends on whether the rights transferred are bona fide rights which have been properly used or whether they belong to the large class of excessive decrees given before conditions were well understood. Where a canal has a small excess of water which has developed from a better use of water or the waterlogging of land which has been irrigated, the transfer of this water does not damage any other right, yet extends the area irrigated and tends to increase the general prosperity of the community. On the other hand, where an appropriation has never been used except for the sole purpose of establishing a so-called right to it, its transfer is bound to affect adversely all rights subsequent to it, and, therefore, to be distinctly harmful to the community as a whole. To illustrate: The Boyd and Freeman Ditch has decrees for appropriations aggregating 99 second-feet, but its capacity is only 25 second-feet. It irrigates 650 acres and, considering the character of the soil, it is evident that 25 second-feet is much more than sufficient to supply all the water needed. In fact, at least 60 second-feet of its first appropriation, priority No. 6, could be sold without impairing in the least the chance of the ditch for full satisfaction throughout the season. If it were possible, and this 60 second-feet right were transferred to the Poudre Valley Canal, for instance, every right subsequent to priority No. 6 would be adversely affected. As the Boyd and Freeman Ditch has never, in fact, used the water, a transfer would be equivalent to taking the water away from subsequent appropriators whose rights would, thereupon, fail a week to three weeks earlier than they do at present.

Some idea of the money value of water rights in the river is given by the cost of water transferred, though it must be understood that these transfers were made some years ago. Parts of priorities No. 2, 19, and 29 were acquired by the North Poudre Irrigation Co. at the

rate of $3,000 a second-foot, and a part of priority No. 17 was acquired by the same company for $2,500 a second-foot. But parts of priorities No. 52 and 66, which were transferred to the North Poudre Canal, cost only $150 a second-foot. Just recently the right of the Mason and Hottel mill race was abandoned to the river on payment of $2,000 per second-foot by the interested canals.

The holding of direct irrigation water in small farm reservoirs is an accepted, well-established custom, due to the recognized economy of time and water the practice promotes. The extension of this custom to regulator reservoirs for the benefit of the whole stream would have a most beneficial effect, but any extension to large reservoirs of individual companies raises the question of where the line should be drawn. In permitting the transfer of 26 second-feet of priorities No. 52 and No. 66 to the North Poudre Canal the court decreed:

> That petitioner (the North Poudre Irrigation Company) may, in times of scarcity of water, and for the purpose of making a more economical use of said water, and at times when other water is not being run in its ditch in sufficient quantity, use Halligan Dam and Reservoir, located on the North Fork of the Cache la Poudre, a short distance above headgate of petitioner's ditch, for the purpose of temporarily catching up said water and obtaining a sufficient head, thence to turn the same into the headgate of the said North Fork ditch without injuriously affecting the vested rights of said respondents or other water users in district No. 3.

In the adjudication of 1882, Warren Lake, which was then hardly more than a fishpond, was given a decree permitting it to draw approximately 15 second-feet of the appropriation of the Larimer County Canal No. 2, but there was no general adjudication of reservoir rights until a decree was handed down by the district court in 1909. By this decree 43 reservoirs were given 57 appropriations on first constructions and enlargements aggregating about 6,000,000,000 cubic feet, or 150,000 acre-feet. Because of inaccurate surveys or lack of surveys, there are many inconsistencies in these decrees, and very few of the decreed appropriations agree with the actual capacity of the reservoir as shown by later careful surveys or by measuring the inflow or outflow. Only a few transfers of reservoir rights have been made. When the North Poudre Irrigation Co. disposed of its interest in Douglass Reservoir the appropriation was retained and transferred to Reservoirs No. 5 and No. 6 to permit these reservoirs to fill from the main river through the Poudre Valley Canal. The appropriation of No. 6 in the North Fork was then transferred to Halligan and No. 15 Reservoirs.

DISTRIBUTION FROM RIVER.

The Cache la Poudre basin is water district No. 3, and to the water commissioner of the district is delegated the duty of turning the water in the stream to the various canals in accordance with the quality,

quantity, and priority of their appropriations. The distribution of the normal flow alone would be a difficult problem, in view of the great daily fluctuation, but the problem is further complicated by the exchanges made, the foreign water and reservoir water carried in the natural channels of the basin, and the seepage return to the stream.

The present incumbent [6] has been water commissioner of the district for more than 25 years; and his long experience, good judgment, fearlessness, and unquestioned honesty insure a just distribution of the water in the stream. He receives each day by telephone reports of all activities within the district, including the flow of the river at various points, changes in demands of the various canals, exchanges desired, and foreign and reservoir water turned into the river for carriage or exchange. With this information before him and his knowledge of the amount of seepage return he is able to determine the amount each canal may properly divert. If the flow in any canal must be increased or decreased he telephones early in the morning to the headgate man of the canal and gives him a new gage height at which the canal must be run until further notice.

With the object of keeping the gain or loss properly placed as the river rises or falls, the order is sometimes reversed and the headgate man is instructed to hold the river below his canal at a certain stage and to divert the remainder of the flow. For instance, when the river reaches the stage at which the appropriation of the Larimer County Canal for 463 second-feet is entitled to draw, the commissioner will direct the headgate man of the canal to pass enough water to keep the river up to a gage of 3.7 at Shipp's bridge just below and to take the remainder into the canal. By holding the Shipp's bridge gage at that point enough water is sent down to supply all prior rights below, and the rise and fall of the canal coincides with the varying supply in the river to which the canal is entitled by that appropriation.

TABLE 6.—*Diversions, in acre-feet, from the Cache la Poudre River in 1916.*

	For storage.												
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
North Poudre Canal.	0	0	3,472	1,712	0	0	0	0	0	1,620	1,080	310	8,194
Poudre Valley Canal[a]	0	0	0	0	0	2,230	1,400	0	0	0	0	0	3,630
Pleasant Valley and Lake Canal	0	0	0	437	0	0	0	0	0	0	0	0	437
Larimer County Canal[b]	0	0	0	370	1,875	2,421	1,990	0	2,746	2,812	0	0	12,214
Jackson Ditch[c]	0	0	0	0	0	0	0	0	0	0	0	0	0

[a] Storage of foreign water and Windsor Reservoir exchange. Direct flow chiefly foreign water to lands under North Poudre Canal.
[b] Storage practically all foreign water.
[c] Larimer County water held temporarily in Long Pond and then exchanged for river water.

[6] John Armstrong.

TABLE 6.—*Diversions, in acre-feet, from the Cache la Poudre River in 1916*—Con.

	For storage.												
	Jan.	Feb.	Mar.	Apr.	May.	June.	Julv.	Aub.	Sept.	Oct.	Nov.	Dec.	Total.
Little Cache la Poudre Ditch [4]	0	522	180	50	300	0	1,176	0	41	898	1,972	420	5,559
Taylor and Gill Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Larimer County Canal No. 2	0	0	0	1,057	533	200	0	0	0	0	0	0	1,790
New Mercer Canal	0	0	0	0	0	0	0	0	0	0	0	0	0
Arthur Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Larimer and Weld Canal	1,410	1,236	0	630	900	0	0	0	935	902	718	690	7,421
Josh Ames Ditch	......	0	0	0	0	0	0	0	0	0	0	0	0
Lake Canal	0	0	0	0	0	0	0	0	0	0	0	0	0
Coy Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Cache la Poudre Reservoir feeder	0	0	0	980	0	0	0	0	0	2,610	3,240	2,420	9,250
Chaffee Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Boxelder Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Fossil Creek Reservoir feeder	0	1,492	1,602	0	0	0	0	0	0	0	0	0	3,094
Greeley Canal No. 2	0	0	0	0	0	0	0	0	420	500	0	0	920
Whitney Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
B. H. Eaton Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Jones Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Greeley Canal No. 3	0	0	0	0	0	0	0	0	0	0	0	0	0
Boyd and Freeman Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Ogilvy Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	1,410	3,250	5,254	5,236	3,608	4,851	4,566	0	4,142	9,342	7,010	3,840	52,509

	For direct irrigation.								Grand total.
	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.	
North Poudre Canal	1,223	7,097	8,592	8,365	3,236	1,396	0	29,909	38,103
Poudre Valley Canal [1]	0	697	1,540	1,946	1,398	0	0	5,581	9,211
Pleasant Valley and Lake Canal	1,357	3,253	4,341	3,543	3,080	1,902	0	17,476	17,913
Larimer County Canal [2]	0	6,887	22,671	17,680	10,691	3,729	0	61,658	73,872
Jackson Ditch [3]	77	1,219	2,349	1,598	1,059	548	0	6,850	6,850
Little Cache la Poudre Ditch [4]	0	959	1,472	2,008	1,751	21	0	6,211	11,770
Taylor and Gill Ditch	365	466	794	786	740	590	276	4,017	4,017
Larimer County Canal No. 2	154	3,562	4,455	2,327	755	68	0	11,321	13,111
New Mercer Canal	31	2,016	2,147	2,059	1,387	414	0	8,054	8,054
Arthur Ditch	491	1,663	1,264	1,703	737	200	79	6,137	6,137
Larimer and Weld Canal	1,237	13,344	33,334	6,908	3,715	2,993	0	61,531	68,952
Josh Ames Ditch	28	43	451	576	368	17	0	1,483	1,483
Lake Canal	0	4,035	5,116	1,992	304	0	0	11,447	11,447
Coy Ditch	0	105	114	366	164	0	0	749	749
Cache la Poudre Reservoir feeder	0	0	0	0	0	0	0	0	9,250
Chaffee Ditch	0	277	64	351	255	0	0	947	947
Boxelder Ditch	0	514	1,042	948	371	40	0	2,915	2,915
Fossil Creek Reservoir feeder	0	0	0	0	0	0	0	0	3,094
Greeley Canal No. 2	1,681	16,431	19,174	4,690	4,045	2,342	0	48,363	49,283
Whitney Ditch	109	451	1,086	1,743	1,587	984	64	6,024	6,024
B. H. Eaton Ditch	169	277	579	1,115	411	278	0	2,829	2,829
Jones Ditch	0	23	312	455	656	94	0	1,540	1,540
Greeley Canal No. 3	1,691	2,973	3,958	4,812	3,714	3,624	438	21,210	21,210
Boyd and Freeman Ditch	0	0	408	421	382	168	0	1,379	1,379
Ogilvy Ditch	607	2,554	1,618	2,071	2,266	1,372	0	10,488	10,488
Total	9,220	68,846	116,881	68,463	43,072	20,780	857	328,119	380,628

[1] Storage of foreign water and Windsor Reservoir exchange. Direct flow chiefly foreign water to lands under North Poudre Canal.
[2] Storage practically all foreign water.
[3] Larimer County water held temporarily in Long Pond and then exchanged for river water.
[4] July storage chiefly Windsor Reservoir exchange.

TABLE 7.—*Diversions, in acre-feet, from the Cache la Poudre River in 1917.*

	For storage.												
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
North Poudre Canal	0	0	495	3,402	6,400	530	0	0	0	[1] 0	0	0	10,827
Poudre Valley Canal	0	0	0	1,476	13,127	2,050	0	0	0	0	0	0	16,653
Pleasant Valley and Lake Canal	0	0	0	460	56	0	0	0	0	120	412	0	1,048
Larimer County Canal	0	0	0	5,137	4,415	514	954	0	4,920	554	0	0	16,494
Jackson Ditch	0	0	0	0	131	383	0	0	0	0	0	0	514
Little Cache la Poudre Ditch	0	0	294	668	2,850	125	316	0	58	2,300	1,704	486	8,801
Taylor and Gill Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Larimer County Canal No. 2	0	0	0	0	1,732	129	73	0	0	0	0	0	1,934
New Mercer Canal	0	0	0	0	0	0	0	0	0	0	0	0	0
Arthur Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Larimer and Weld Canal	406	1,260	2,212	700	7,220	0	0	0	0	0	1,400	0	13,198
Josh Ames Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Canal	0	0	0	0	0	0	0	0	0	0	0	0	0
Coy Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Cache la Poudre Reservoir feeder	0	0	686	1,260	0	0	0	0	0	2,140	2,212	1,720	8,018
Chaffe Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Boxelder Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Fossil Creek Reservoir feeder	2,568	2,164	1,358	0	0	0	0	0	0	0	588	0	6,678
Greeley Canal No. 2	0	0	0	0	0	0	0	0	360	280	0	0	640
Whitney Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
B. H. Eaton Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Jones Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Greeley Canal No. 3	0	0	0	0	0	0	0	0	0	0	0	0	0
Boyd and Freeman Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Ogilvy Ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2,974	3,424	5,045	13,103	35,931	3,731	1,343	0	5,338	5,394	6,316	2,206	84,805

[1] 41 acre-feet from Halligan carried for storage in Stuchel Lake for Wellington water supply.

	For direct irrigation.								Grand total.
	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.	
North Poudre Canal	0	118	8,198	12,369	10,895	2,149	0	33,729	44,556
Poudre Valley Canal	0	0	662	2,475	358	51	0	3,546	20,199
Pleasant Valley and Lake Canal	453	202	4,945	6,171	3,495	1,945	0	17,211	18,259
Larimer County Canal	0	8,087	22,626	27,897	10,557	1,813	0	70,980	87,474
Jackson Ditch	0	86	1,261	2,391	1,254	666	15	5,673	6,187
Little Cache la Poudre Ditch	0	0	1,855	1,977	1,543	204	0	5,579	14,380
Taylor and Gill Ditch	264	231	560	810	784	560	0	3,209	3,209
Larimer County Canal No. 2	0	0	4,096	6,795	396	121	0	11,408	13,342
New Mercer Canal	0	47	3,075	3,592	1,214	243	0	8,171	8,171
Arthur Ditch	0	281	1,495	2,241	453	73	0	4,543	4,543
Larimer and Weld Canal	587	2,013	30,910	25,923	3,322	4,480	0	67,235	80,433
Josh Ames Ditch	0	0	178	698	532	0	0	1,408	1,408
Lake Canal	0	213	5,454	6,156	158	0	0	11,981	11,981
Coy Ditch	0	0	0	204	363	41	0	608	608
Cache la Poudre Reservoir feeder	0	0	0	0	0	0	0	0	8,018
Chaffee Ditch	0	0	286	514	198	0	0	998	998
Boxelder Ditch	0	0	1,272	1,255	1,645	991	0	5,163	5,163
Fossil Creek Reservoir feeder	0	0	0	0	0	0	0	0	6,678
Greeley Canal No. 2	0	2,164	18,349	25,064	3,442	1,581	0	50,600	51,240
Whitney Ditch	0	0	843	1,478	1,635	997	0	4,953	4,953
B. H. Eaton Ditch	0	329	1,071	1,261	989	477	21	4,148	4,148
Jones Ditch	0	0	85	29	381	457	0	952	952
Greeley Canal No. 3	275	946	2,899	4,544	4,191	3,046	0	15,901	15,901
Boyd and Freeman Ditch	0	96	134	354	538	254	0	1,376	1,376
Ogilvy Ditch	0	686	2,145	2,892	3,161	1,881	11	10,776	10,776
Total	1,579	15,499	112,399	137,090	51,540	22,030	47	340,148	424,953

Almost without exception the distribution is made in strict accordance with appropriations and priorities. Little attention is paid to the small ditches above the mouth of the canyon or at the head of tributaries entering below the canyon. The general feeling is that irrigation from these small ditches does not affect to any great extent the total supply of water available below, except possibly in very dry years, and that the trouble and expense of keeping track of them would more than counterbalance any good which might result. Below the canyon on the main stream a few small ditches divert practically at will on early excessive decrees, but the greater part of this water is wasted directly back to the river and the total supply is diminished by only a small amount. Another exception is the practice of allowing some canals to "accumulate" water for a few days. For instance, the appropriation of 175 second-feet of the Larimer County Canal No. 2 usually fails about July 10, and instead of allowing the canal to draw a varying and dwindling head for perhaps 10 days, it is permitted to draw a good head for 3 or 4 days and is then cut off entirely. By general consent certain exceptions which work out to the best advantage are made in the case of reservoirs. The Cache la Poudre and the Fossil Creek Reservoirs have first call on the water which heretofore passed through the Mason and Hottel mill race and they may be filled slowly with the assurance that they can be topped out when the spring flood comes down. The filling of Claymore Lake may also be delayed with the assurance that it can be completely filled in a week during the flood period. So during a part of the storage season water which might be demanded by these reservoirs may be diverted to others which have less chance of filling either on account of late priorities or small intakes.

DIVERSIONS FROM THE RIVER IN 1916 AND 1917.

Diversions from the river for the 2 years of the investigation are shown in Tables 7 and 8 and figure 3. The ratio of diversions for storage to the total diversion was 14 per cent in 1916 and 20 per cent in 1917, but in neither year was the total available storage capacity used. These figures do not include storage in the mountain reservoirs of the basin, but were these included the figures would not be changed greatly.

Diversions for direct irrigation begin in April and continue until the first part of October, though the greater part of the demand is from April 15 to September 15. Water for storage is drawn throughout the year except in August, but practically all the water stored between June 15 and the end of the season is foreign water or "Windsor exchange." The large amount of storage in April and May, 1917, is accounted for by a high river and heavy rains which decreased the demand for water for direct irrigation.

DUTY OF THE RIVER.

The average available supply of water in the Cache la Poudre amounts to 375,000 acre-feet, which includes the normal flow of the river and its tributaries and 35,000 acre-feet of foreign water, but does not include the seepage return to the river. Applied to the 225,000 acres irrigated in the valley it gives for the stream, as a whole, a duty of 1.67 acre-feet per acre; or, expressed differently, each second-foot of the average annual discharge irrigates 434 acres. This high general duty is made possible only by the large percentage of the flow held in storage for use at critical times and by the large amount of return seepage which is used several times over again.

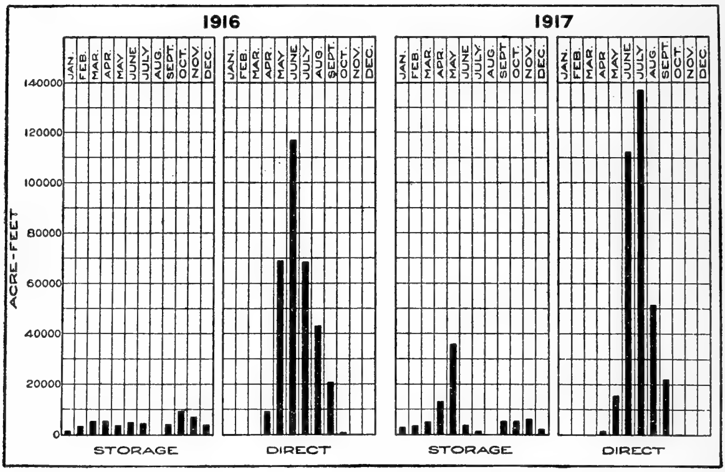


FIG. 3.—Diversions from the Cache la Poudre River for storage and for direct irrigation compared for the 2 years of the investigation.

THE CONSUMPTIVE DUTY.

The water actually consumed, or the consumptive duty, may be arrived at by considering in addition the water which passes into the South Platte River from the Cache la Poudre River, Lone Tree Creek, and various canal wasteways dumping into the South Platte or Crow Creek. In 1916 the available supply exclusive of seepage return was 336,000 acre-feet, and 79,000 acre-feet passed out of the valley. The net consumption of 257,000 acre-feet on the 218,000 acres irrigated that year gives a duty of 1.18 acre-feet per acre. In 1917 the supply was 608,000 acre-feet, and 309,000 [7] acre-feet passed into the South Platte. The net consumption of 299,000 acre-feet on the 225,000 acres irrigated that year gives a duty of 1.33 acre-feet per acre. As the water supply during 1916 was slightly below normal

[7] Partly estimated.

and in 1917 was far above normal, it seems reasonable to assume that the average consumptive duty is approximately 1.25 acre-feet per acre.[8]

NONPRODUCTIVE AND WASTE LAND.

With the object of determining how the farm land of the valley is utilized and the proportion of nonproductive and waste land, careful surveys were made of 7½ sections of land at different points in the valley. A summary of the data obtained by these surveys is contained in Table 8.

TABLE 8.—*Utilization of farm land in the Cache la Poudre Valley.*

	3 sections near Greeley (per cent).			3 sections northeast of Fort Collins (per cent).			1½ sections northeast of Fort Collins (per cent).		
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
Cultivated	89.2	92.8	84.5	81.4	90.7	57.2	71.0	....	....
Irrigated but not cultivated	.4	2.4	.0	4.4	19.7	.0	8.0	....	....
Public roads	2.3	2.4	1.9	2.1	2.4	1.1	1.6	....	....
Private roads	.5	1.0	.0	.3	1.0	.0	1.1	....	....
Railroad right of way	.9	2.6	.0	.0	.0	.0	.0	....	....
Farmstead	2.1	3.1	1.4	2.0	3.7	.8	4.9	....	....
Wood lots	.0	.0	.0	.4	1.9	.0	.0	....	....
Canals	.3	1.6	.0	.7	3.6	.0	2.0	....	....
Field laterals	3.0	4.9	2.0	2.9	5.4	1.1	2.0	....	....
High land	.0	.0	.0	1.6	16.8	.0	.0	....	....
Seepage land	.0	.0	.0	2.7	14.1	.0	.7	....	....
Marginal waste	1.3	2.5	.3	1.5	4.6	.6	8.7	....	....

The 3 sections near Greeley include some of the most highly developed land of the valley, with prices ranging from $300 to $400 per acre. It is smooth, gently sloping land, easy to cultivate and irrigate. The water rights supplying it are excellent, and wet spots which developed after years of irrigation have been drained. On this land the nonproductive area is at a minimum. The 3 sections near Fort Collins are less valuable, ranging in price from $150 to $200 per acre. The land is more rolling and includes some high spots or knolls not reached by the ditches and some wet spots which have not yet been drained. The section and a half northwest of Fort Collins has been farmed by tenants for some years and shows the result of neglect. A low percentage of the land is cultivated and the marginal waste is particularly high. The high percentage of land included under the head of farmstead was in this case due to a number of pens for sheep feeding.

The best farm practice requires that the percentage of land devoted to nonproductive use be reduced to a minimum, and that there be no real waste of land. Public roads will require 2.3 per cent of the area of farms in a section. Private roads should not require more than 0.5 per cent. At present the roads are 12 feet wide and

[8] This calculation does not take into account return seepage from Poudre Valley land going directly into the South Platte. Taking this into account would reduce slightly the quantity of water actually consumed.

generally unimproved, but might profitably be widened and made permanent by grading and systematic maintenance work. Farmsteads should not be held to a minimum and considerations of comfort and health should govern their size. For field laterals not more than 2.5 to 3 per cent should be required, the percentage varying with the crop, the slope of the land, and other conditions. Marginal waste should not exceed 1 per cent. In general, not more than 2 feet is required at the side of a field and at the end not more than 6 to 8 feet.

CANAL SYSTEMS.

In the section of the Cache la Poudre Valley under investigation there are about 25 irrigation canals diverting from the river. Two or three of these irrigate only a few acres each, but 23 were considered of sufficient importance to be included in the investigation. Beginning at the head of the stream and listing them in the order in which they head these canals are: North Poudre Canal or North Fork Ditch; Poudre Valley Canal; Pleasant Valley and Lake Canal or Highline; Larimer County Canal; Water Supply & Storage Co. Canal or Ditch; Jackson Ditch or Dry Creek Ditch; Little Cache la Poudre Ditch; Taylor and Gill Ditch; Larimer County Canal No. 2; New Mercer Canal; Arthur Ditch, Tom Ditch, or Fort Collins Canal; Larimer and Weld Canal or Eaton Ditch; Josh Ames Ditch; Lake Canal; Coy Ditch; Chaffee Ditch; Boxelder Ditch; Greeley Canal No. 2, or Union Colony Canal No. 2, or Cache la Poudre Canal; Whitney Ditch; B. H. Eaton Ditch; Jones Ditch; Greeley Canal No. 3, or Union Colony Canal No. 3; Boyd and Freeman Ditch; and Ogilvy Ditch. The areas irrigated by the more important of these canals in 1916 are shown in Plates X to XIII.

Excepting many small ditches which are owned by individuals, the canals of the valley are organized in some cooperative form. There are two irrigation districts and a number of informal partnerships, but the great majority are joint-stock companies.

The development of irrigation in the valley was so rapid that nearly all the canal systems had been successfully completed before financing by irrigation districts became necessary. For this reason there are only two districts in the valley, the Park Creek and the Greeley-Poudre. The Park Creek district includes a few sections under the North Poudre Canal and receives its water from that canal and from rights in Fish Creek. The Greeley-Poudre district covers a large area between Greeley and Carr, but financial and legal difficulties several years ago caused a suspension of activities after only a part of its construction program had been carried out.

The partnerships are rarely formally organized, but operate in accordance with customs which have to a certain extent been crystallized in the laws of the State. Often each partner does an amount

of cleaning and other maintenance work in proportion to his interest in the ditch, though he is required by law to do only his share from the headgate to the point at which his lateral diverts. For the distribution of water in the ditch, division boxes or weirs are used very generally and a continuous flow is delivered until the supply falls short or the demand decreases. A short supply is usually rotated among the partners, each receiving an even amount of water for a time proportionate to his interest. Many laterals of canals are handled in this manner.

Many of the cooperative companies were originally organized as such, the capital stock being placed at the cost of construction of the canal and sold for cash or issued to the builders in proportion to the work done by each. Others were controlled originally by corporations organized to build canals and to derive profits from the sale of water rights, but, in accordance with terms commonly contained in the water right contracts, cooperative companies were organized by the owners of water rights to take over the systems after a certain number of rights had been sold. In such cases shares were issued in proportion to the water rights held. In general, a share of stock of a cooperative company represents a proportionate part of the water supply of the ditch at any time and this water may be used on any land served by the system, subject, of course, to due notice of a desire to change the point of delivery. Holdings of stock are not restricted in any manner and vary with the water requirements or finances of the individual. This, together with variations in supply and demand due to wet and dry seasons and crop changes in rotation systems, has given rise to the common practice of renting shares or water for a season or less.

The organization of the cooperative companies shows no unusual features. The stockholders elect a board of directors who in turn elect officers to conduct the business of the company. These include always a president, secretary, treasurer, and superintendent. Riders, headgate men, and gangs for repair and maintenance work are employed by either the superintendent, president, or the directors. Engineers, hydrographers, and office help are employed only for special work or for short periods.

The ordinary expenses of the cooperative companies are met by levying annual assessments on the capital stock. These assessments vary from a few cents to a dollar or two an acre, but the average is close to 25 cents. Several canals of the valley in their capacity as common carriers of reservoir water make their charges for this service high enough to defray most of their expenses. In the case of the Greeley Canal No. 2 the income from carrying reservoir water is sufficient to meet all ordinary expenses and assessments are levied only on special occasions. However, the money comes out of the

farmer's pocket whether it is in the form of an assessment or a carriage charge.

The canal structures of the valley show various designs and types of construction, but in general permanent structures of reinforced concrete are replacing the old timber structures. Diversion dams are rock and brush, timber, or concrete. Rock and brush dams are used by only a few of the small ditches on the lower reaches of the river. The majority of the dams are simple structures consisting of piles of rock cribs topped by heavy timber decks on which there are permanent crests or standards for flashboards. Wings may be of masonry, concrete, or timber and seepage underneath is usually cut off by a row of sheet piling. A dam of this type is shown in Plate II, figure 1. The majority of the newer dams are of reinforced concrete set on piles or rock crib, and having well-designed overflow lips and suitable sluices to scour the channels past the canal intakes. A dam of this type is shown in Plate I, figure 1. The crest of the Larimer County Dam (Pl. I, fig. 1) was found to be too low for certain stages of the river and was raised 12 inches with 3 by 12 planks fastened to iron pins sunk in the crest. In Plate I, figure 2, is shown another type of concrete dam in which the water is held up by flashboards.

The drift guard at the head of the Larimer and Weld Canal, shown in Plate II, figure 2, is of the same general design as others in the valley. The structure itself and the individual timbers of the grating are placed at such an angle that the drift tends to slide downstream instead of lodging. A few canals depend on booms of logs chained end to end and anchored so that they swing out in front of the gates.

Headgates are made of timber, concrete, or stone and are fitted with wooden or iron gates raised by some combination of screw and lever, or rack and pinion. A type of gate and lifting device is shown in Plate III, figure 1. Wasteways and sand sluices are of similar design. Some of the canals use an adaptation of the Land sand gate with diagonal ducts to cut out the greater part of the sand near the bottom of the canal.

In the construction of the canals of the valley flumes are avoided even at great expense as is evidenced by the construction shown in Plate III, figure 2. Some of those which were built are being eliminated by the construction of tunnels or inverted syphons, the longest in the valley, a half-mile flume along the side of the canon at the head of the North Poudre Canal, being replaced by a tunnel 1,600 feet in length through solid rock. There still remain a number of timber or concrete flumes for crossings of less than 200 feet, and one of these is shown in Plate IV, figure 1. Rating flumes at the head of canals are usually of concrete or timber, though a few of masonry

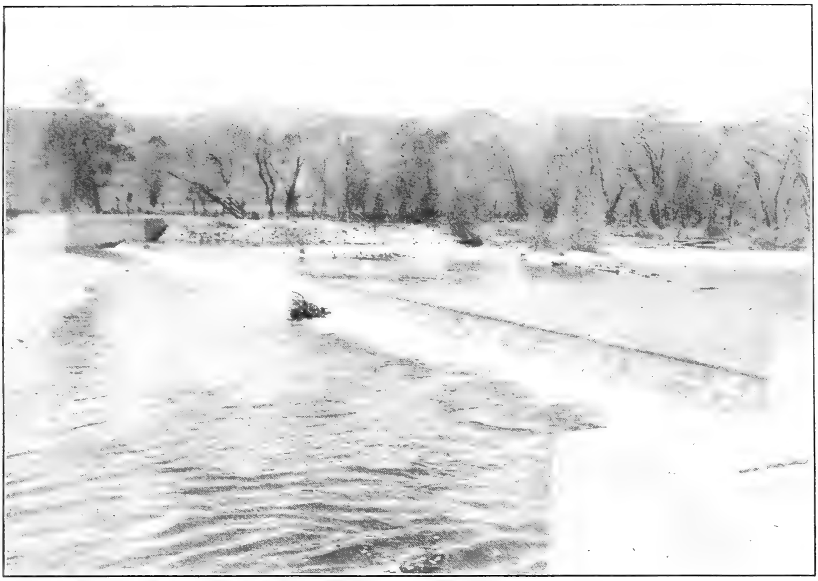


FIG. 1.—DIVERSION DAM OF THE LARIMER COUNTY CANAL.

FIG. 2.—DIVERSION DAM OF THE B. H. EATON DITCH.

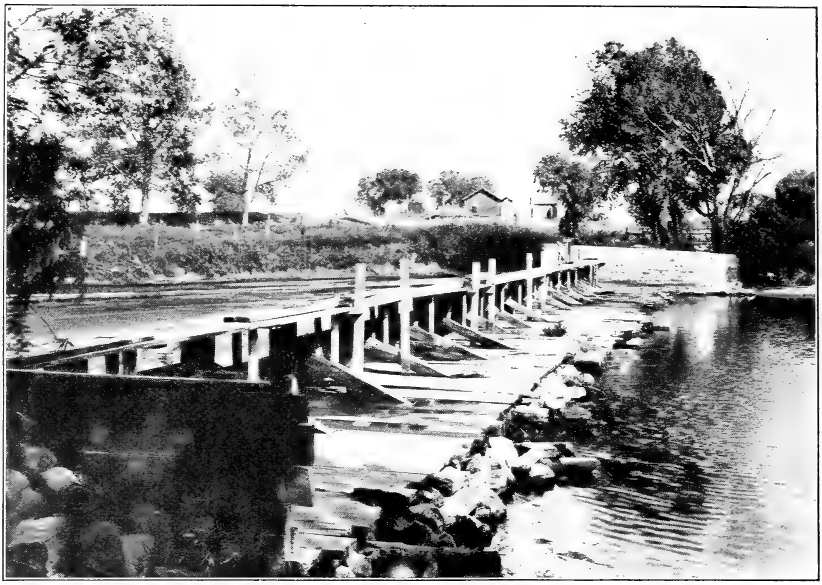


FIG. 1.—DIVERSION DAM OF THE GREELEY CANAL NO. 2.

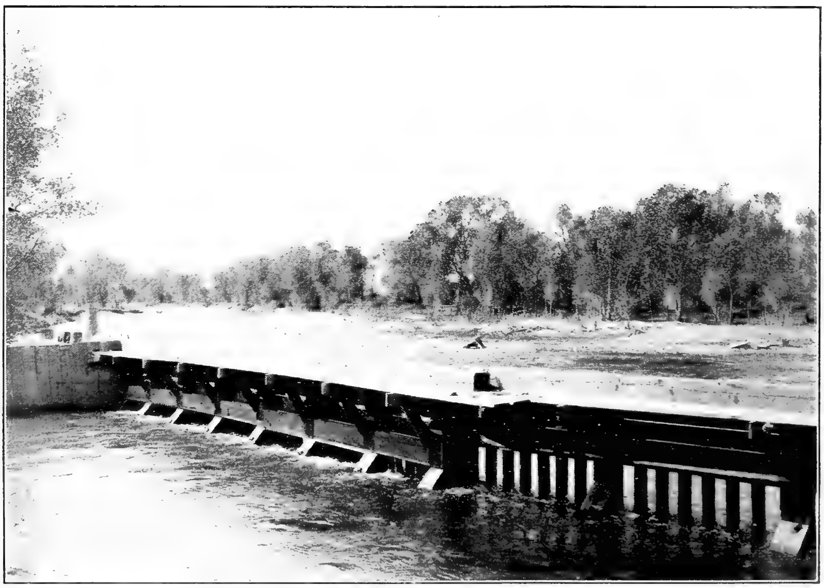


FIG. 2.—DRIFT GUARD AT HEAD OF LARIMER AND WELD CANAL.

FIG. 1.—HEADGATE OF THE GREELEY CANAL NO. 2.

FIG. 2.—LINE OF THE POUDRE VALLEY CANAL ROUNDING A ROCK BLUFF.

FIG. 1.—FLUME CARRYING TAIL OF LITTLE CACHE LA POUDRE DITCH OVER DRY CREEK.

FIG. 2.—FLUME OR CHUTE CARRYING LONG POND WATER TO THE LARIMER AND WELD CANAL AND LINDENMEIER LAKE.

are found. Almost without exception they are designed or installed so that accurate measurements in them are almost impossible. In Plate IV, figure 2, is shown a flume or chute carrying water from Long Pond to the Larimer and Weld Canal and Lindenmeier Lake.

In the original construction of the canals of the valley contours were followed closely and only a few drops were necessary. These are generally of fair design and well constructed. A drop on the North Poudre system is shown in Plate V, figure 1, and in Plate V, figure 2, is shown a drop at the tail of a south-side ditch. Some of the canals with slightly excessive grades have been corrected by the construction of timber or concrete checks, in which part of the control is by flashboards. A typical check is shown in Plate VI, figure 1.

Laterals receive their supply from the main ditch through lines of tile ranging in diameter up to 24 inches. The upper end of the tile is set in a concrete bulkhead, and the flow through the pipe is controlled by an iron gate sliding in grooves in an iron framework which fits over the end of the tile. The gate stem is threaded, and the regulation is by one or two wheels working on these threads and against crosspieces. This gate is the Powell gate, so-called after its designer, B. F. Powell, of Rocky Ford.[9]

The most common device for measuring water to laterals is the rectangular weir which is found in sizes ranging from $1\frac{1}{2}$ to 10 feet in length of crest. The installation of these weirs is usually faulty, and the most accurate measurements can not be obtained with them. Bottom and end constructions are usually deficient, and entrance velocities are almost invariably too high. A combined weir and drop on a lateral of the Larimer County Canal is shown in Plate VI, figure 2. Division boxes are also very common for the distribution of water in small canals and laterals. Where an overfall is provided the division is fairly good, but otherwise it may or may not be. Typical division boxes are shown in Plate VII. The device used by the Pleasant Valley and Lake Canal for measuring water to users is shown in Plate VIII, figure 1. The crest of the weir is 4 inches above the bottom of the box, and the depth over the crest is measured on a plug about a foot back from the weir. The slots in the sides are intended for 2 by 12 inch planks, which are supposed to float in the slots and act as baffles.

With few exceptions, all lateral headgates and measuring devices are under the exclusive control of the canal company. Deliveries are made at the head of the lateral, and the canal company disclaims all responsibility for the distribution of water from the lateral and for the maintenance of the lateral. A continuous delivery of a prorata part of the flow is the method in common use on the majority of the

[9] A drawing of this gate appears on page 39 of O. E. S. Bulletin No. 229.

canals, but when the supply becomes short some system of rotation between sections of the canal is instituted. The exception is the North Poudre Canal, which delivers on demand an allotment of water made at the beginning of the season. Under certain restrictions, reservoir water handled by ditches as carriers only is delivered on demand. Descriptions of some of the delivery systems of the canals of the valley are given in later sections of this report.

Maintenance problems in the valley present no new difficulties and on the whole give less trouble than might be expected. The Cache la Poudre is comparatively free from silt and sand, and deposits in canals are usually limited to short stretches at the head and at curves. These deposits are removed with scrapers in the spring or fall. Canal grades which were proper for the original canals were too heavy when these canals were enlarged, and at one time there was much erosion of banks and bottoms, but this condition has been corrected by the construction of checks or drops at proper points. For local erosion brush mattresses and rock riprapping are used, as shown in Plate VIII, figure 2. For river protection, rock riprap or rock-filled cribs, as shown in Plate IX, figure 1, are used. Breaks occur occasionally and are repaired in the ordinary manner with scrapers, care being taken to secure a good bond between the old and new material, to pack the new material carefully, and to raise the water on the new section as slowly as the necessity for water will warrant. The clear water and hot sunshine are favorable to the growth of moss, and by the first of July it begins to cause trouble on many of the canals. A moss-filled ditch is shown in Plate IX, figure 2. So far no successful method has been devised to prevent its growth or to remove it. Generally it is allowed to grow until it almost chokes the canal. The water is then cut out of the canal and the moss allowed to dry for two or three days. This helps to a certain extent, but is not a solution of the problem. Winter conditions have to be contended with by only two or three canals carrying water for storage in reservoirs. The winter supply rarely exceeds 100 second-feet, and little trouble is experienced in handling it.

LARIMER & WELD CANAL.

Early in 1879 the Larimer & Weld Irrigation Co. was incorporated with a capital stock of $200,000 to take over the construction of the Larimer & Weld Canal, on which construction work had been begun in 1878, and to sell water rights. The water-right contracts provided that when rights to the capacity of the canal had been sold, 4 shares of the capital stock of the company were to be turned over to the holder of each right so that control of the company would pass to the owners of rights. After 366 rights had been disposed of the owners of rights felt that the capacity of the canal had been

reached and, upon applying to the courts, were upheld in their contention. At present the company is on a mutual basis with 1,423 shares of a par value of $100 outstanding.

The water rights sold by the company called for the delivery of a continuous flow of 1.44 second-feet throughout the irrigation season when it was available from the river. At first one right was considered sufficient for 80 acres, but at present the average area served by a right, or 4 shares, is 160 acres. In 1880 rights, or the equivalent share, sold for $400; in 1882, $1,000; in 1887, $1,200; and in 1917, $4,500. Their present high value is due to the fact that there is still considerable land under the canal susceptible of irrigation, while the water supply is limited.

The expenses of the company are met by assessments levied on the capital stock and tolls collected for carrying reservoir water. In 1916 and 1917 the assessments were, respectively, $5 and $12.50 per share, the higher assessment being for the purpose of retiring some of the outstanding obligations of the company. For carrying water to fill Windsor Reservoir and others about $1,350 was received each year. For carrying and distributing reservoir water about $7,000 was received each year. Current expenses average about $15,000 each year, or at the rate of approximately 35 cents per acre irrigated.

The canal heads just north of Fort Collins in section 34, township 8 north, range 69 west, and tails in Long Draw, a tributary of Crow Creek. Excluding the 16-mile extension beyond Owl Creek, the main canal is 40 miles long. The bottom width at the head is 30 feet and the slope of the sides is 1½ to 1. The grade is 3 feet per mile for the first 3 miles, 2 feet per mile for the next 32 miles, and 1½ feet per mile at the end. Its capacity is 750 second-feet. There are about 75 miles of main laterals operated by lateral companies and several hundred miles of small laterals and sublaterals.

In the tabulation shown on page 15 will be found a statement of the water rights of the canal. In acquiring the right to enlarge the old No. 10 ditch it was necessary for the company to give the original owners a free, unlimited, perpeteual right to as much water as they could use on the lands they had previously irrigated, as long as the canal was drawing from the river. For this reason the first two appropriations are available for general use only when not required by the No. 10 rights.

The distribution from the canal of water received on direct appropriations presents no notable features. The company controls only the main canal and its responsibility ends with the delivery of the water to the laterals which are all owned and controlled by separate companies or individuals. The canal is in three sections, each of which is handled by a ditch rider. Diversions from the

canal are made through Powell gates which are kept locked so that they may be raised or lowered only by the ditch rider. The water delivered is measured over a rectangular weir, the depth over the weir being determined from tables carried by the rider, which show the depth to be carried over any crest length from 1 foot to 12 feet for any number of rights from $\frac{1}{4}$ to 68. In general, the water supply from the river is prorated among the users in accordance with the number of shares of stock which they hold, and to get the water to which he is entitled the user has only to notify the rider of the main ditch, or else the rider of the lateral from which he gets his supply, who will in turn notify the rider of the main canal. In times of very short supply a system of rotation of the supply between sections of the canal is instituted to avoid the wasteful practice of prorating a small supply. The company recognizes and encourages the practice of rotation of water among users, and the stockholders may have their water delivered to any lateral upon request. No records are kept of the delivery of water received on direct appropriations. Reservoir water and water received on direct appropriations are not run at the same time, and usually after the running of reservoir water is started the small amount received on appropriations from the river goes to make up losses in the canal or to pay for water advanced to the canal earlier in the season by the Windsor Reservoir.

Considerable care is used in the distribution of reservoir water, and complete records are kept by the secretary of the company. Before any water is delivered all carriage charges must be paid and credit entered on the books of the secretary. The delivery record of each user occupies one large sheet, 8 by 27 inches, of a loose-leaf book. Heading each sheet is the name of the owner, with a space in which may be entered the name of the tenant. At the left of the sheet there are blanks opposite the names of the various reservoirs in which may be entered the total number of rights of each with which the user is credited. Below are columns in which any debits or credits may be entered during the season. The right side of the sheet is devoted to records of delivery, with columns for every day from July 15 to September 15 and others in which are entered the name of the person ordering the water delivered and the lateral to which it was delivered. Under the dates are entered the numbers of "rights" delivered on that date. While this form of record is too large to be handled conveniently, the advantage of having the entire record on one sheet is obvious. Deliveries and credits may be compared at a glance for the benefit of users who inquire as to the standing of their accounts, and in addition there is little chance of any user exceeding his credit.

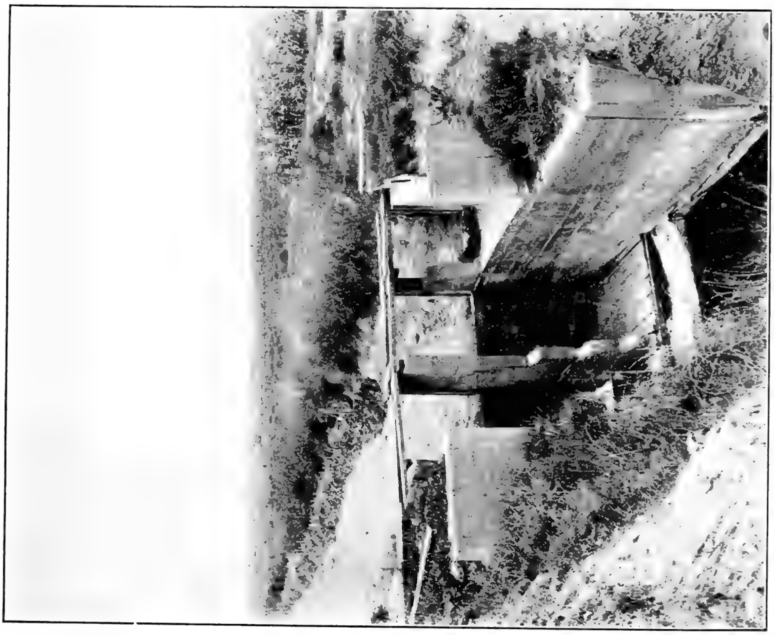


FIG. 1.—CONCRETE DROP ON THE INLET TO THE COAL CREEK RESERVOIR OF THE NORTH POUDRE IRRIGATION CO.

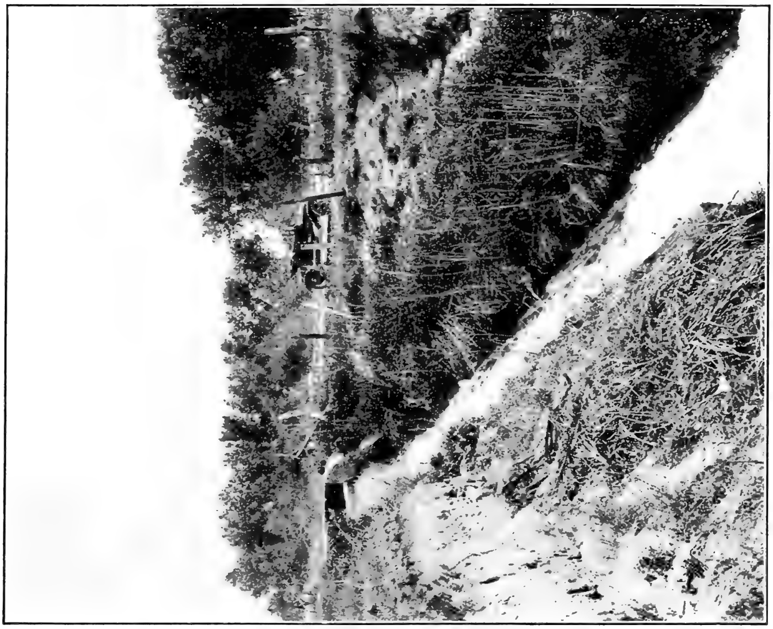


FIG. 2.—DROP AND CHUTE TO MAIL CREEK AT THE TAIL OF THE LARIMER COUNTY CANAL NO. 2.

FIG. 1.—CHECK IN THE LARIMER AND WELD CANAL.

FIG. 2.—WEIR AND DROP AT THE HEAD OF THE CULVER-BARTELS LATERAL OF THE LARIMER COUNTY CANAL.

FIG. 1.—COMMON TYPE OF DIVISION BOX IN WHICH THE DIVIDING BOARD IS MOVABLE AND IS HELD IN PLACE BY A CHAIN HOOKED OVER NAILS IN A CROSS PIECE.

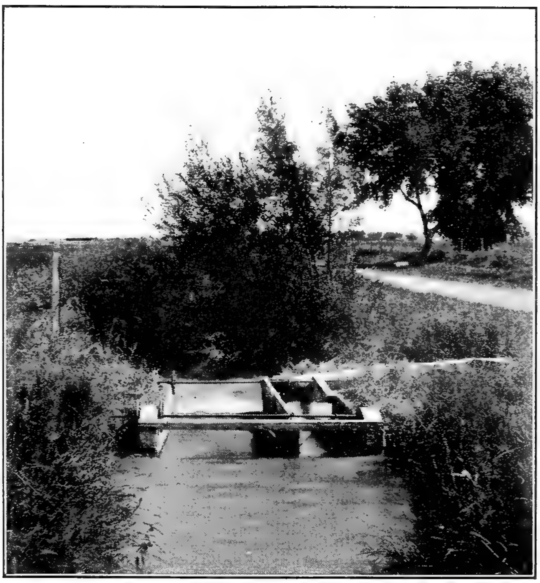


FIG. 2.—DIVISION BOX ON THE ROBERTS LATERAL OF THE LARIMES AND WELD CANAL. THE DIVIDING BOARD IS CONTROLLED BY WHEELS WORKING ON THREADED RODS FASTENED TO THE BOARD.

FIG. 1.—DEVICE FOR MEASURING WATER DELIVERED TO THE LATERALS OF THE PLEASANT VALLEY CANAL.

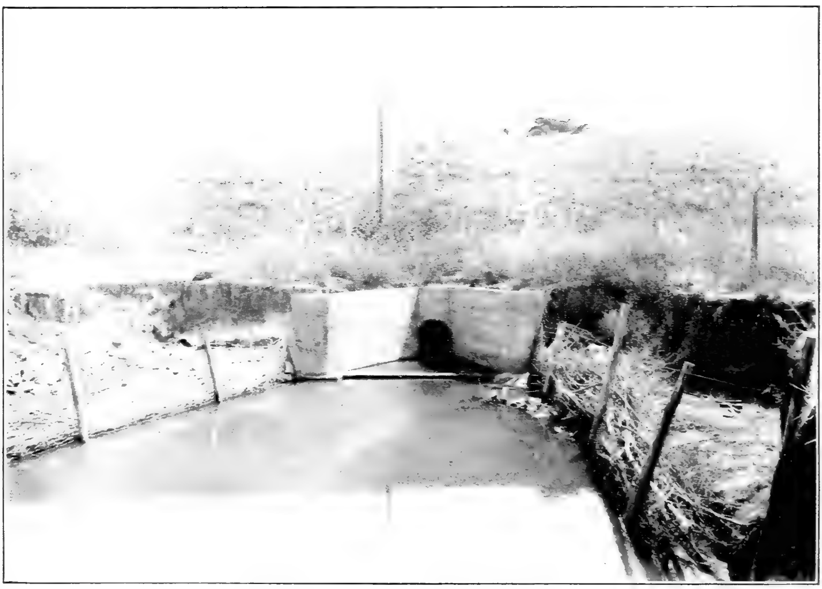


FIG. 2.—BRUSH MATTRESS BELOW OUTLET OF KLUVER LAKE TO STOP EROSION FROM BACKWASH.

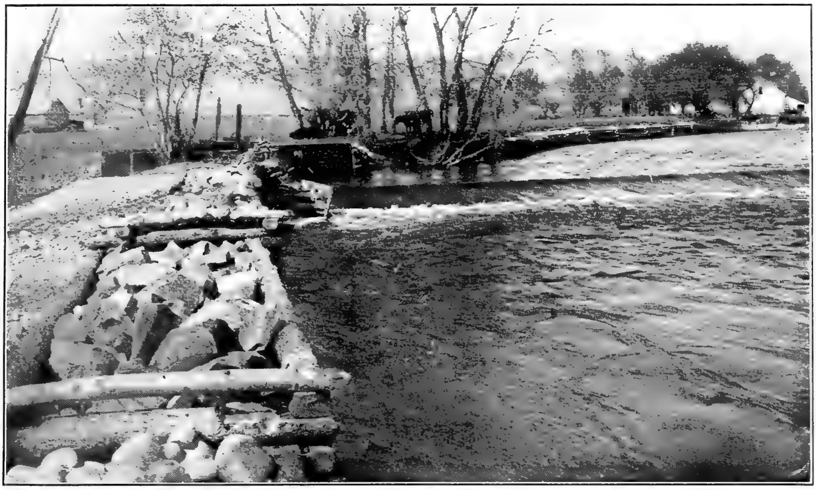


FIG. 1.—ROCK-FILLED CRIBS USED AS RIVER PROTECTION AT THE HEAD OF THE ARTHUR DITCH.

FIG. 2.—MOSS IN THE OUTLET OF THE ROCKY RIDGE RESERVOIR.

The company rules provide that reservoir water will be carried when 250 rights are called for, but that the water will be cut off when the demand drops below 200 rights. Water is carried for $10 per right and rights of other reservoirs must be made equal to those of Terry Lake or Windsor Reservoir, which range from a 16 to a 22 day run of $1\frac{1}{4}$ second-feet. Single day runs are carried at a minimum charge of $1. On each right carried by the canal there is delivered to the lateral of the owner of the right 0.72 second-foot. To supply this 0.72 second-foot at the head of the lateral the company requires that there be delivered to the canal 1.25 second-feet, the difference taking care of losses in transit and inaccuracies and inequalities in distribution. Under a fairly constant demand and with better wire installations this margin of safety could no doubt be cut by 0.15 second-foot.

Demands for water are usually made by phone or in person to the secretary, who enters on a card provided for the purpose the name of the owner of the water, the name of the person ordering the water, the number of rights to be run, the lateral to which the water is to be delivered, and the period for which it is to be delivered. On account of the length of the canal, two days' notice is required for water to be delivered or cut off. Thus, to secure delivery Wednesday morning, water must be ordered before 1 o'clock Monday afternoon. At 1 o'clock each day the secretary begins the preparation of a list of the demands for the second day following, by revising the sheet of the preceding day. Orders which have expired are scratched off and new orders are entered, after which typewritten copies are made for the superintendent and the various ditch riders. The sheet is in the form shown below.

Sixteenth run, Saturday, Aug. 17, 1918.

Owner or renter.	Rights demanded.	Rights from Windsor.	Rights from Terry or other reservoirs as indicated in last column.	Lateral to which water is to be diverted.	Period to be run.
Anderson, J. P.	2	2	....	Owl Creek	15th to 19th.
Anderson, L. G.	$1\frac{1}{2}$	....	$1\frac{1}{2}$	Lucas	
Beard & Anderson	2	1	1	Decker	
Weber, Henry	1	....	1	Roullard	

Résumé: Windsor, $181\frac{1}{2}$; Terry, 77; Worster, 10; Douglass, $17\frac{1}{2}$. Total demanded, 286 rights.

Upon receipt of this sheet the ditch riders prepare cards for each lateral, showing the amount of water ordered by each stockholder under the lateral. On the second morning following the water is

turned out to the various laterals as ordered and the cards are tacked on the lateral gates to serve as a guide for distribution by the riders of the laterals. The system of distribution from the laterals is practically the same as for the main canal, the water being measured over weirs except in a few cases where division boxes are used.

The copy of the order sheet sent to the superintendent reaches him the same afternoon, thus giving him 36 hours to increase or decrease the supply in the canal to meet the demand. To assist him with this part of the work the canal employs an expert hydrographer who measures all the water received by the canal for carriage and keeps a record which shows the number of cubic feet delivered direct by each reservoir or its account by exchange and the number of rights of that reservoir delivered by the canal. At the end of the season these quantities must balance, but the economical and satisfactory operation of the canal requires that there be much "swapping" of credits during the season, as in 1916, when Douglass Reservoir rights had been supplied for over a month before any Douglass water was received by the canal. In general, the supplies in Curtis, Kluver, and Douglass Reservoirs are drawn at a uniform rate, while the fluctuation in demand is taken care of by increasing or decreasing the outflow of the others, chiefly Terry Lake. On Sundays and at other times when there is a short demand, instead of cutting off at its source the reservoir water being received through Dry Creek, it is turned into Terry Lake and, under proper credit, held there for later use. On account of the long inlet canal and the difficulty of filling, the greater part of the surplus reservoir water, at the end of the season, is usually left in Windsor Reservoir No. 8. The lands irrigated are shown in Plate X.

LARIMER COUNTY CANAL.

The Larimer County Canal was initiated in 1880, when the Larimer County Ditch Co. was incorporated to build a canal and sell water rights under it. Arrangements were made with the owners of the Smith Ditch by which the Larimer County Ditch Co. acquired their right of way and in the spring of 1881 actual construction work on the canal was begun. From the start it was realized that the water supply directly from the river would be insufficient, and the construction of reservoirs to increase the supply was begun soon after. The company did not prosper, and in 1892 the system was taken over by the Water Supply & Storage Co., which had been organized by holders of rights in the ditch. This is a cooperative company with a capital stock of $60,000 divided into 600 shares of a par value of $100. The present value is close to $6,000 per share.

Expenses of this company are met by assessments levied on the capital stock. These assessments average about $100 per share, pro-

ducing a fund of $60,000. Of this, $20,000 is to cover interest charges on indebtedness and $10,000 goes into a sinking fund. Ordinary operation and maintenance costs are covered by the remaining $30,000, which is at the rate of approximately 65 cents per acre irrigated.

The Water Supply & Storage Co. system includes 11 reservoirs with an aggregate capacity of 26,000 acre-feet, 4 canals tapping other watersheds and diverting water into the Cache la Poudre, the Larimer County Canal, and an interest in the Jackson Ditch.

The Larimer County Canal is the distributing canal for the system and also supplies the lower reservoirs of the system. It heads in section 13, township 8 north, range 70 west, and extends eastward 75 miles to Owl Creek, into which it tails. The area irrigated is shown in Plate XI. The canal is 24 feet wide on the bottom, has a grade ranging from 1.32 to 3.16 feet per mile, and will carry 600 second-feet. There are about 50 laterals, with length of 150 miles.

At the head of the Cache la Poudre River the company owns four ditches which divert water from other sheds and turn it into the Cache la Poudre to be stored in Chambers Lake or diverted below into the Larimer County Canal. The Skyline Ditch intercepts water from tributaries of the Laramie River, the Cameron Pass Ditch diverts from the Michigan River shed, and two ditches divert the headwaters of the Grand River. For carrying this foreign water in the channel of the Cache la Poudre the water commissioner deducts 5 per cent for losses in transit.

The company owns an interest in the Jackson Ditch, acquired by purchase from the Larimer & Weld Reservoir Co., and a further interest was obtained by an exchange arrangement with individuals under the Jackson Ditch whose farms lie partly above the ditch. Contracts covering this exchange arrangement provide that the Water Supply & Storage Co. acquires a definite amount of stock of the Jackson Ditch, and the water secured on it is tailed into Long Pond. In exchange the individual acquires the right to an equal amount of water, less a small per cent for loss, from the Larimer County Canal throughout the season for his high land. The Water Supply & Storage Co. benefits by the arrangement because it receives the Jackson water throughout the season constantly, while the demand on the Larimer County Canal is intermittent.

Three of the reservoirs of the company, Chambers, Lost, and Laramie Lakes, with an aggregate capacity of approximately 7,000 acre-feet, are located at the head of the Cache la Poudre and in addition to storing water of the Cache la Poudre may be used to hold up foreign water brought over from other sheds.

Of the lower reservoirs Black Hollow, with a capacity of 5,760 acre-feet, is on the line of the canal about 25 miles from the tail of

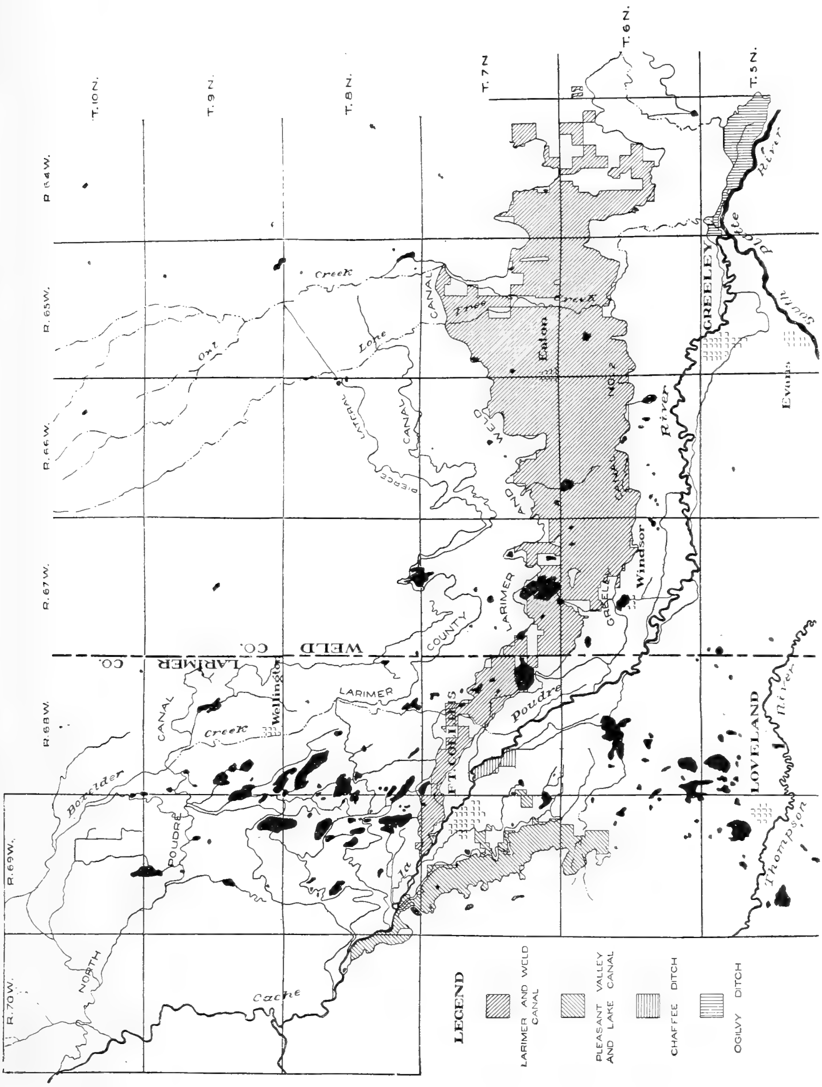
the ditch. Owing to its position this reservoir does away with the usual operation troubles at the lower end of long canals. The remaining reservoirs of the system are supplied by the Larimer County Canal, and the water stored in them may be used only by exchange. These reservoirs are listed below, with their capacities:

Reservoir:	Capacity in acre-feet.
Curtis Lake	780
Rocky Ridge Reservoir	4,730
Kluver Lake	815
Reservoir No. 4	987
Long Pond	4,017
Lindenmeier Lake	918
Richards Lake	1,056

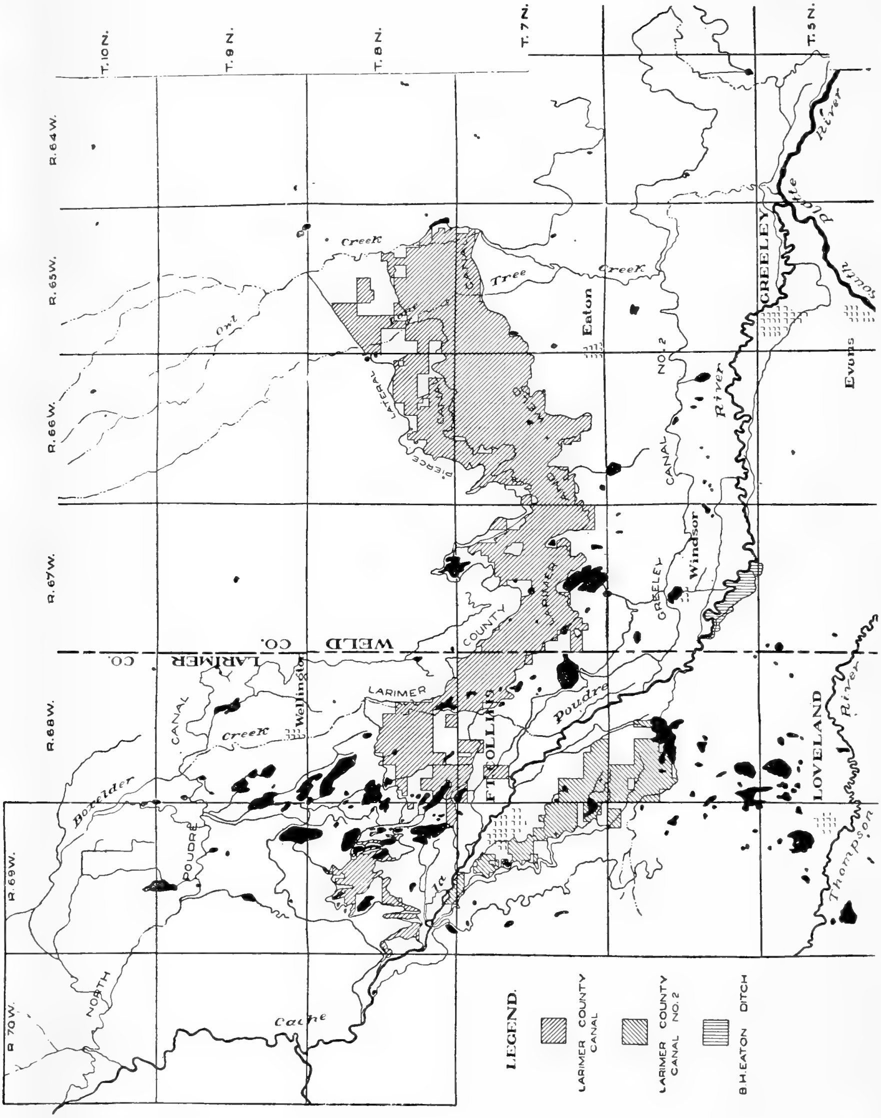
The water rights of the company in the Cache la Poudre are listed on pages 14 and 16. The company also has decrees for appropriations made in other districts, but these are not listed. The owners of rights in the Smith Ditch, with a single exception, exchanged their rights for stock in the company. With this exception the appropriations of the company are owned jointly.

The system of water delivery on the Larimer County Canal is comparatively simple so far as the user is concerned. At any time there is water in the canal for direct irrigation he is entitled to his pro rata share and may obtain it by notifying the ditch rider that he wishes it turned out. The water delivered is measured over rectangular weirs, and the riders carry tables from which the proper depth over the weir may be taken directly. These tables are based on the delivery of 1.677 second-feet, or 40 " farmer's inches," to the share. At this rate the 600 shares of the company require 406 second-feet, and this demand is supplied by a flow of 485 second-feet in the canal. Incidentally this indicates a loss of approximately 16 per cent in the canal. However, the canal carries a full supply only a short time during the season, and deliveries are usually made at the rate of 20 or 30 " farmer's inches " to the share. To determine the depth over the weir for the delivery of less than 40 inches to the share, the number of inches is multiplied by the number of shares to be satisfied and the result is divided by 40. The quotient is the equivalent number of shares on a basis of 40 inches to the share, and the corresponding depth is taken directly from the table.

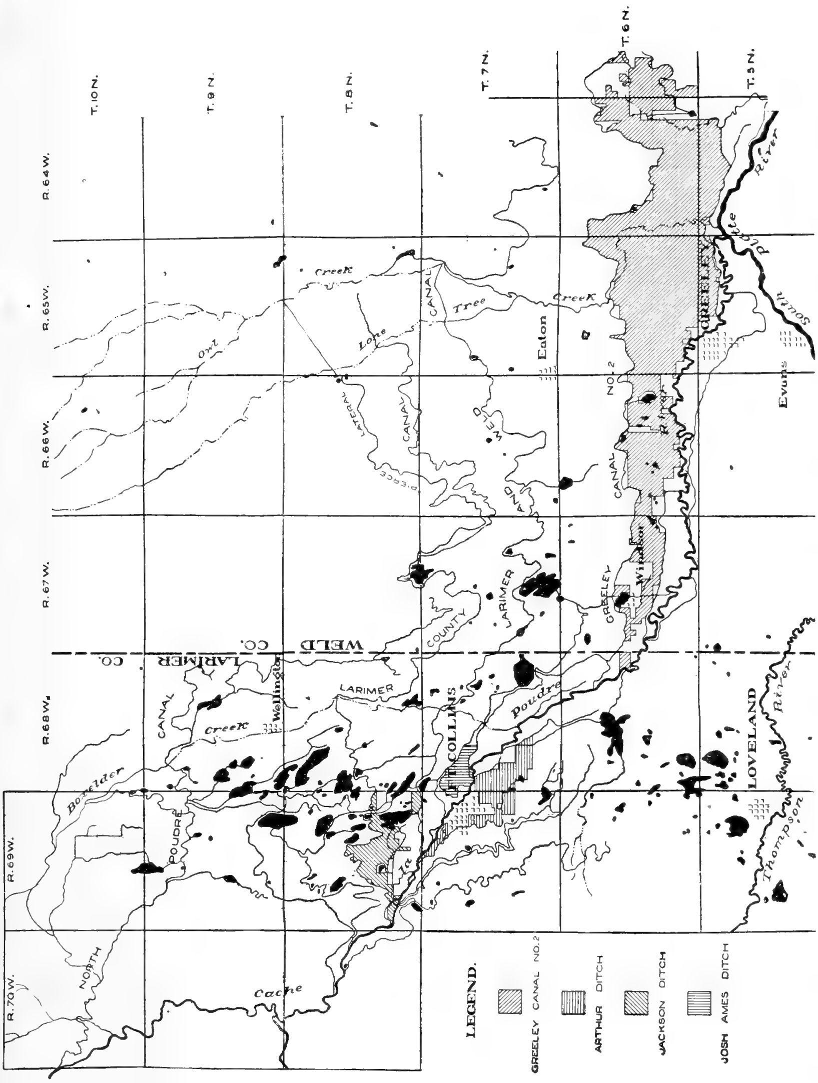
The amount of water to be carried in the canal at various times is determined by the superintendent and the board of directors and depends on the supply in sight and the disposal of it necessary to finish the season in good shape. At the high stage of the river plenty of water is usually received from the mountain ditches, on exchange and on direct appropriations, but as the supply diminishes enough water is held up to insure proper irrigation of late crops, such



AREAS IRRIGATED IN 1916 BY THE LARIMER AND WELD CANAL, THE PLEASANT VALLEY AND LAKE CANAL, THE CHAFFEE DITCH, AND THE OGILVY DITCH.



AREAS IRRIGATED IN 1916 BY THE LARIMER COUNTY CANAL NO. 2 AND THE B. H. EATON DITCH.



AREAS IRRIGATED IN 1916 BY THE GREELEY CANAL NO. 2, THE ARTHUR DITCH, THE JACKSON DITCH, AND THE JOSH AMES DITCH.

as potatoes and sugar beets. At times of extreme shortage runs of 5 to 8 days are made, at intervals of 5 to 8 days, and 20 to 30 inches are delivered to the share.

Records kept include frequent readings of all reservoir gauges, from which the available supply may be determined; records of discharge of the main canal at the head and of the various mountain ditches of the system; records of water delivered to each stockholder, and records of all water received or delivered in exchange. The records of delivery are on cards and show for each user each day of the season the number of shares he drew water on, the rate in inches per share, and the depth over the weir.

GREELEY CANAL NO. 2.

The Greeley Canal No. 2, known also as the Union Colony Canal No. 2, or the Cache la Poudre Canal, was built by the Union Colony at Greeley. Preliminary work was done in 1870 and the first construction was completed in 1871. Enlargements were made in 1874 and 1877. In 1878 the Cache la Poudre Irrigation Co. was organized by the farmers under the canal to take over control from the colony, and a large sum was spent in improving the headworks and in bettering the alignment of the canal. The present company, the New Cache la Poudre Irrigation Co., was organized in 1890 to undertake various improvements of the system. The company has a capital stock of $100,000 divided into 2,500 shares of a par value of $40, of which 2,496 have been issued. Each of the original rights is represented by 8 shares of the present company. In 1916 rights sold for $2,800, which is equivalent to an increase of 900 per cent in value.

The entire cost of operation and ordinary maintenance of the canal has lately been met by charges of the company for carrying reservoir water, and assessments were levied on the stock only for special expenses. Thus in 1916 current expenses were $6,736, while tolls for carrying reservoir water amounted to $7,961. The average cost of operation and maintenance is at the rate of approximately 20 cents per acre irrigated.

The main canal heads in section 11, T. 6 N., R. 68 W., and ends 26 miles below at Lone Tree Creek, but an 18-mile extension tails in Crow Creek. At the head of the canal it is 34 feet wide on the bottom, carries water to a depth of 4 feet, and is on a grade of 3.2 feet per mile. The maximum head carried during 1916 and 1917 was 558 second-feet. There are 40 companies owning and operating the larger laterals and the total length of laterals is estimated to exceed 300 miles.

The water rights of the company are shown in the tabulation on page 15, and the area irrigated in 1916 in Plate XII.

The distribution of both river and reservoir water from the Greeley Canal No. 2 is handled in much the same manner as from the Larimer and Weld Canal. The company controls only the main canal and its responsibility ends when the water is delivered to the lateral. Because of its short length the canal is divided into two sections only, each of which is handled by a ditch rider under the direction of the superintendent. Diversions from the canal are made through Powell gates, which may be raised or lowered only by the ditch rider, and the water delivered is measured over weirs. Before the delivery of reservoir water is begun the user may get his pro rata share of the water in the canal by applying to either the rider on the main ditch or the rider on his lateral. After the canal begins carrying reservoir water the small amount of river water received is used to supply reservoir demands and an equivalent credit is accumulated in either the Windsor Reservoir or the Cache la Poudre Reservoir. When a sufficient credit has been accumulated to supply a day's run to each right, each stockholder under the canal is credited with his pro rata share, which will be delivered to him on demand.

Reservoir water is delivered by the company on demand of the user a day in advance, orders received before 1 p. m. being filled the following morning. The unit used is 1 second-foot for a day, and the company charge for carriage is $1. The secretary of the company is required to keep a record of the reservoir water handled and for this purpose he has a journal, order book, and ledger. All credits of water reported are first entered in the journal, after which they are posted in the ledger. The order book page is designed for a period of 10 days and is divided into columns in which are entered the date, name of user, page of ledger containing his account, a notation to show whether the order was received by telephone or otherwise, name of person giving order, units or "rights" ordered, lateral to which water was to be delivered, and character of order, whether open or for a definite period, after which are 10 columns for noting the units delivered each day. These records are also posted in the ledger, which is in the form below:

Form of reservoir water accounts, Greeley Canal No. 2.

HERMAN SANDERS.

Debit.			Credit.		
Aug. 6	68	2.00	Aug. 3. No. 2	99	16.50
7	68	2.00	15. Windsor	98	25.50
* * * * *	*	*	* * * * *	*	*
Sept. 18	68	2.00	25. Windsor (W. Lang)	105	25.50
19	68	1.50			
		67.50			67.50

On the debit side the number in the second column refers to the page in the order book, and the third column shows the number of units carried. On the credit side the second column shows the source of the water, the last two credits being Windsor Reservoir water rented from W. Lang. The third column carries references to pages in the journal. The last column shows the units credited, and as the charge per unit is $1, also dollars paid for carriage.

At 1 o'clock each day the secretary begins the preparation of a list of demands for the following day, showing the name of the user, the rights or units ordered, and the lateral to which the water is to be delivered. A copy is furnished to each rider and from it he figures out the amount which he must turn to each lateral the following morning. As in the case of the Larimer and Weld Canal the reservoir from which the supply for a particular day is drawn will depend not so much on the demands for its rights as upon the requirements for the most satisfactory operation of the canal.

THE NORTH POUDRE CANAL.

Surveys of canals to irrigate the territory now covered by the North Poudre Canal were made in 1878 and 1879 by local men, but they could not raise the funds necessary to carry their projects forward, and nothing came of their efforts. In 1881, F. L. Carter-Cotton and others organized the North Poudre Land, Canal, & Reservoir Co., secured the financial support of the Travelers' Insurance Co., and began work on the canal. By 1884 construction had been completed to Boxelder Creek, but no water could be obtained from the river that year and very little in the 2 years following. In 1887 the promoters quit and control was assumed by the insurance company. This company operated the system until 1896, when it sold out to F. C. Grable. In 1901 the system passed into the possession of the present owner, the North Poudre Irrigation Co. This company was originally capitalized at $400,000, but in 1913, to absorb the Mountain Supply Ditch Co., the capital was increased to $500,000, divided into 10,000 shares of a par value of $50. In 1916 these shares were selling at $112. Both land and water rights were sold by the company, and with each 80-acre right went 25 shares of the company. Holdings now vary widely and range from 10 to 35 shares for 80 acres.

The company has outstanding over $500,000 in bonds and short-time obligations of from $25,000 to $50,000 have lately been carried from year to year. Regular assessments are levied on the capital stock at the rate of $5 per share and occasionally an extra assessment is levied for some special purpose. In 1917 the cost of operation and maintenance was about $27,000, or close to 80 cents per acre irrigated.

The original water supply of the canal was of practically no value and the constant endeavor of the company to build up a reliable supply has resulted in the acquisition of various reservoirs, canals, and rights.

The main canal of the system heads in the North Fork of the Cache la Poudre in section 12, T. 10 N., R. 71 W., and is about 25 miles long, including 4 or 5 miles of natural channel in Campbell Draw. The bottom width at the head is 22 feet, the maximum depth of water carried is 3.3 feet, and the maximum capacity is 200 second-feet. There is comparatively little irrigation from this canal, but it supplies the lower reservoirs of the system from which the distributing laterals extend.

The Scurvin Ditch leaves the main canal a short distance above Campbell Draw and supplies a large area along the Boxelder but above the main canal. It also serves as an intake canal for Reservoir No. 15.

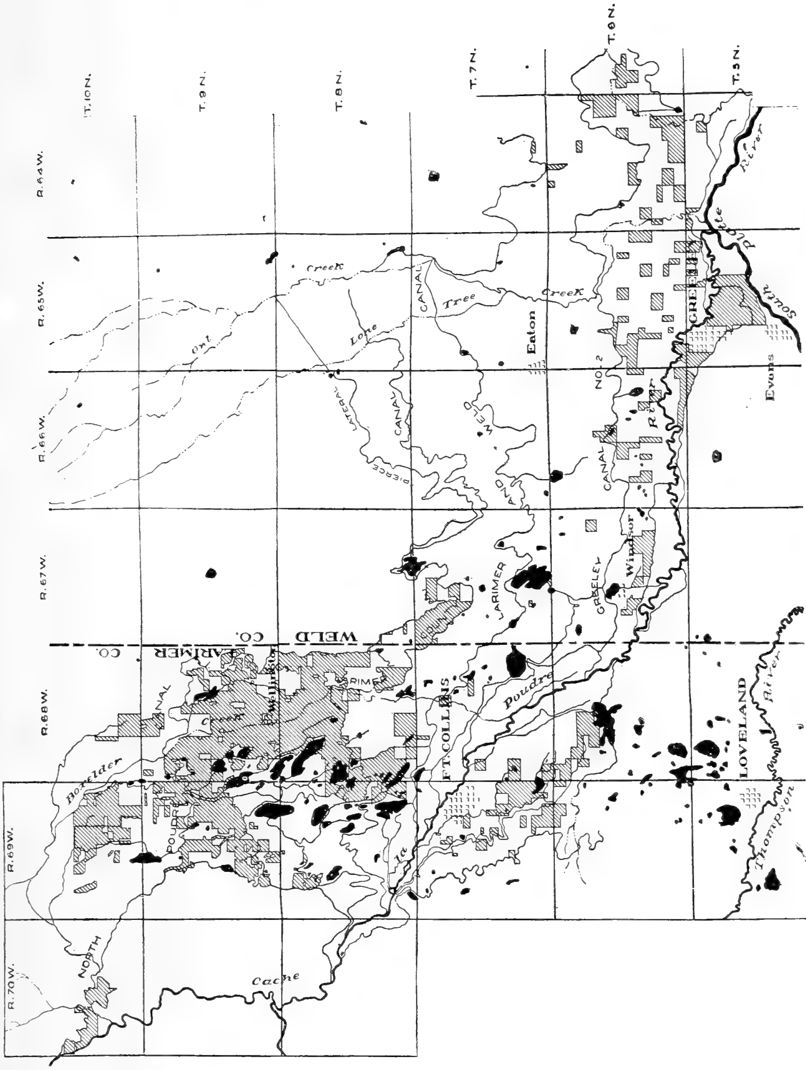
The company is also interested in the Poudre Valley Canal to the extent of a first right to the use of the canal as a carrier both to store water in Reservoirs No. 5 and No. 6 and for direct irrigation of lands just north of Fort Collins.

In addition, the company owns the Michigan Ditch, which diverts water from tributaries of the Michigan River into the Cache la Poudre. Water from this ditch may be used directly through the Poudre Valley canal or in the main canal by exchange.

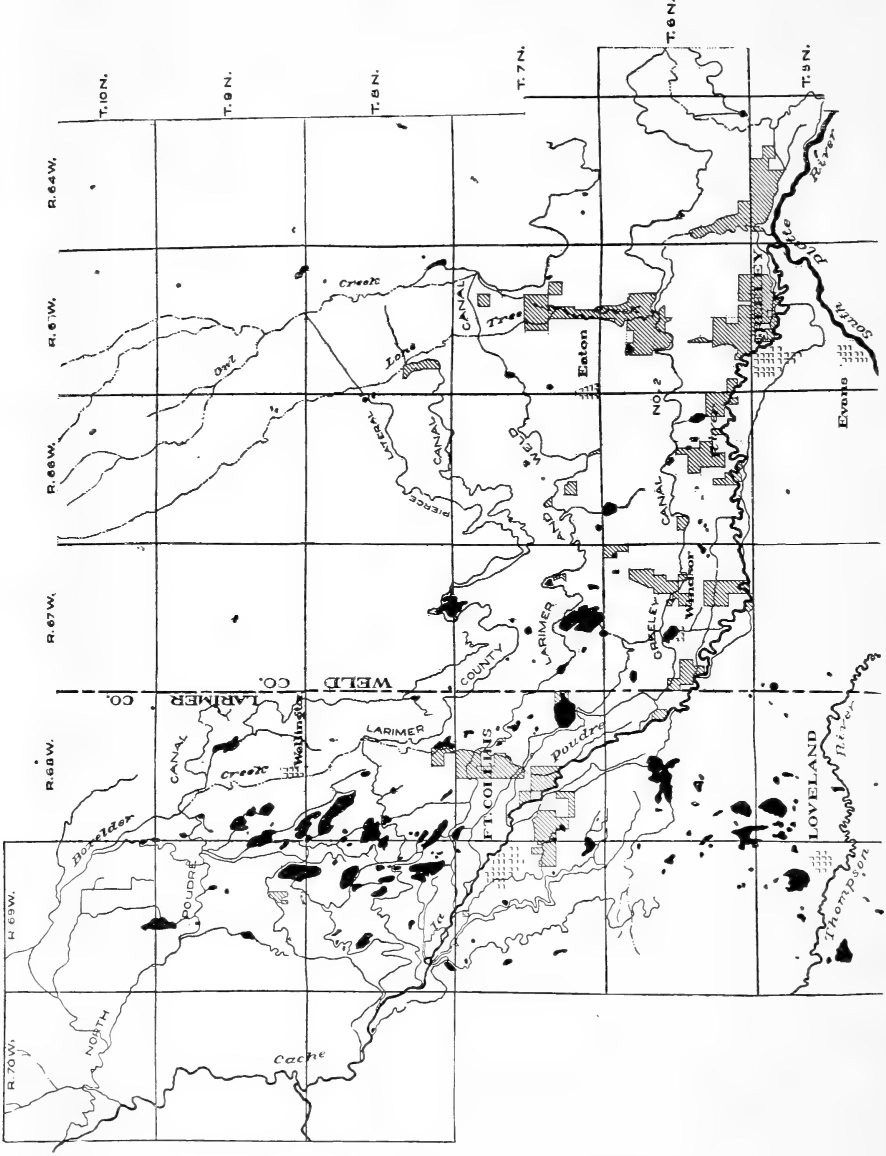
The total storage capacity available for the system is close to 53,000 acre-feet, as is shown by the accompanying list of the company's reservoirs. The most valuable reservoir of the company is Halligan, which is in the bed of the North Fork several miles above the head of the main canal. In addition to commanding all the land irrigated by the system "temporary" storage of direct flow rights in it is permitted by court decree. Reservoir No. 15 derives its value from the fact that it also is above the main canal and commands a large part of the total acreage of the system.

Water stored in Reservoirs No. 5, and No. 6, Fossil Creek Reservoir, and Portner Reservoir can be used only by exchange, but they are essential features of the system. The available supply for the Fossil Creek Reservoir has been such that its filling was practically assured each year. The rights of the North Poudre company in this reservoir are subject, however, to the prior satisfaction of preferred rights aggregating 150,000,000 cubic feet or 3,444 acre feet.

The company is part owner of the Boxelder Ditch & Reservoir Co. and secures several hundred acre-feet of stored water from this source each year.



AREA IRRIGATED IN 1916 BY WATER OF THE NORTH POUDRE IRRIGATION CO. AND BY WATER ON PREFERRED RIGHTS IN FOSSIL CREEK RESERVOIR.



IRRIGATED ACREAGE ON WHICH SEEPAGE WAS THE MAIN WATER SUPPLY IN 1916.

Under an old agreement with B. G. Eaton for carrying water from Worster for certain of his lands under the North Poudre Canal the company secures 160 acre-feet of stored water from that reservoir.

Reservoirs of the North Poudre Irrigation Co.

Reservoir.	Capacity (acre-feet).	Reservoir.	Capacity (acre-feet).
No. 1	445	Tenney	345
No. 2	3,880	Mountain Supply No. 2	150
No. 3	2,870	Bubble	225
No. 4	2,795	Cameron Pass	815
No. 5	5,740	Halligan	6,428
No. 6	10,215	No. 15	5,510
Caverly	170	Fossil Creek	12,050
Stuchell	170	Portner	595
Coal Creek	4,095		

The water rights of the company are shown in the tabulations on pages 14 and 16. The area irrigated in 1916 is shown on Plate XIII. No dependence could be placed in the original appropriation of the canal and the necessity for a more reliable supply accounts for the large number of transferred rights. With the exception of the William Calloway right and the rights of the Brown ditches, these appropriations are owned outright by the company. The former is limited in use to a certain tract and the latter are carried for the use of individuals under a perpetual contract. To permit a better use the transferred rights owned by the company may be stored temporarily in Halligan Reservoir until a sufficient amount has been accumulated for an economical head for the main canal.

The system of water delivery under the North Poudre Canal is different from that of any other canal in the valley. At the beginning of the season the superintendent determines the amount of water in storage and estimates the amount in sight on direct appropriations. On this basis an allotment is made which in average years is close to 125,000 cubic feet per share. This water is delivered upon demand at any time during the season and at any rate, subject of course to certain requirements of operation. To discourage extensive growing of crops requiring late irrigation, heavy deductions of credits are made for absorption losses as the season progresses. Water credits remaining on June 1 are reduced by 10 per cent; those remaining on July 1 are reduced by 25 per cent, and on August 1 a reduction of 50 per cent is made. Under this system, if the farmer starts the season with an allotment of 100,000 cubic feet per share and uses no water until August 1, he will then be entitled to only 33,700 cubic feet per share.

When the farmer wishes to draw water he notifies the ditch rider or the office of the company in Wellington the day before and states

the size of the head he desires turned out. The riders meet every morning at the office, list the demands, and compare them with the credits remaining. Then they cover their " beats " and set the various gates to deliver the amounts demanded. The water is measured over wooden rectangular weirs and the proper depth over the weir is determined from tables which show for each size of weir the discharge in Colorado statute inches, cubic feet per hour, and cubic feet per 24 hours. The rider's records include a daily report and a separate delivery account for each user. The daily report of deliveries shows the name of the farmer drawing; size of weir; depth over weir; hours run and total cubic feet delivered during the day, the day being reckoned from midnight to midnight. In the record of delivery kept by the rider each user is given a separate account in which is entered a complete record of all water drawn. In addition there is kept at the office at Wellington a water ledger containing a record of all credits and of all deliveries as compiled from the daily reports of ditch riders. From this ledger the state of any account can be determined at a glance.

GROSS DUTY FOR CANALS.

To serve as a basis for computing the duty of water measured at the heads of canals of the valley, the total area and the crops irrigated by each canal in 1916 and 1917 are shown in Table 9. Each canal is credited with all the land and crops irrigated by it, either alone or in combination with other canals. Overlapping of areas served by two or more canals, is the cause of considerable duplication of acreage in the table. The effect of the war may be noted in the large increase in food crops as well as in the appreciable increase in the total acreage irrigated.

In Tables 10 and 11 the water used by the canals of the valley in 1916 and 1917 is shown with a proper segregation of direct flow and stored water. Under the head of direct flow has been included water on direct appropriations, foreign water not stored, and certain exchange water. Thus, Windsor Reservoir water delivered to Greeley Canal No. 2 in payment for No. 2 water taken above in exchange is classed as direct flow. On the other hand river water taken by the Larimer County Canal in exchange for water in Lindenmeier Lake is classed as stored water.

TABLE 9. *Total acreage and crops irrigated by the canals of the valley in 1916 and 1917.*

1916.

Canal.	Alfalfa.	Grain.	Sugar beets.	Potatoes.	Beans.	Corn.	Peas.	Garden and orchard.	Native hay.	Pasture.	Miscellaneous.	Total.
North Poudre Canal[1]	12,932	9,281	3,687	105	1,441	281	103	175	348	751	488	29,592
Poudre Valley Canal[2]	340	118	6	......	......	1	....	6	74	120	....	665
Pleasant Valley and Lake Canal	3,590	1,293	966	......	......	178	....	321	127	359	82	6,916
Larimer County Canal	19,305	10,247	7,377	4,216	1,978	867	607	97	91	1,849	522	47,156
Jackson Ditch	917	577	247	......	......	77	....	98	4	326	11	2,257
Little Cache La Poudre Ditch[3]	405	285	478	......	4	1	....	13	32	155	195	1,568
Taylor and Gill Ditch	120	27	135	......	......	6	....	78	....	49	8	423
Larimer County Canal No. 2	3,549	1,028	1,564	......	5	101	....	161	....	146	35	6,589
New Mercer Canal	2,924	670	1,085	......	......	103	....	203	2	160	36	5,183
Arthur Ditch	1,203	455	442	......	6	2	....	62	....	42	33	2,245
Larimer and Weld Canal	21,510	10,376	10,805	6,254	3,821	531	441	....	....	1,329	877	55,944
Josh Ames Ditch	270	124	387	......	20	......	....	4	....	111	71	987
Pioneer Ditch	100	......	......	......	......	36	....	....	....	31	....	167
Lake Canal	2,868	1,054	2,217	39	162	6	40	6	....	870	57	7,319
Coy Ditch	98	24	41	......	......	21	....	....	....	38	....	222
Chaffee Ditch	125	92	92	......	......	......	....	....	....	144	....	453
Boxelder Ditch	661	361	489	......	8	......	....	2	....	168	15	1,704
Greeley Canal No. 2	12,365	4,239	8,054	2,174	3,372	940	939	193	....	1,116	779	33,978
Whitney Ditch	744	683	1,062	......	82	49	44	....	241	963	39	3,907
B. H. Eaton Ditch	166	175	439	......	32	......	18	....	....	453	9	1,292
Jones Ditch	53	164	161	......	66	......	29	....	73	118	13	677
Greeley Canal No. 3	615	552	1,119	......	248	144	55	....	....	482	211	3,427
Boyd and Freeman Ditch	62	44	255	......	16	......	4	....	17	212	....	610
Ogilvy Ditch	1,006	294	365	88	553	155	....	....	....	......	21	2,482
Seepage	5,001	2,415	3,476	996	1,174	123	261	....	....	909	806	15,161

1917.

Canal.	Alfalfa.	Grain.	Sugar beets.	Potatoes.	Beans.	Corn.	Peas.	Garden and orchard.	Native hay.	Pasture.	Miscellaneous.	Total.
North Poudre Canal[1]	13,807	10,985	3,941	214	2,833	867	....	155	184	221	348	33,550
Poudre Valley Canal[2]	326	175	29	......	6	4	....	6	74	45	....	665
Pleasant Valley and Lake Canal	3,437	2,049	837	......	25	104	....	267	86	307	231	7,343
Larimer County Canal	17,012	10,194	5,221	7,227	5,048	475	137	106	91	1,561	747	47,819
Jackson Ditch	765	744	247	......	7	61	....	98	16	305	18	2,261
Little Cache La Poudre Ditch[3]	389	366	420	......	18	26	....	13	29	143	139	1,543
Taylor and Gill Ditch	93	40	140	......	......	17	....	80	....	35	80	423
Larimer County Canal No. 2	3,564	1,077	1,583	3	17	92	....	156	....	134	26	6,652
New Mercer Canal	2,615	1,043	1,104	1	27	109	....	197	2	97	41	5,236
Arthur Ditch	1,215	471	426	......	......	......	....	159	....	10	48	2,329
Larimer and Weld Canal	18,902	10,884	7,175	10,888	6,569	872	54	7	323	1,325	985	57,984
Josh Ames Ditch	230	282	262	......	8	63	....	3	....	58	33	939
Pioneer Ditch	104	......	20	......	......	......	....	....	....	28	....	132
Lake Canal	2,672	1,484	1,876	148	145	10	....	7	....	727	27	7,096
Coy Ditch	102	4	63	......	......	30	....	....	....	24	....	223
Chaffee Ditch	166	70	138	......	......	......	....	....	....	79	....	453
Boxelder Ditch	760	383	357	......	21	......	....	2	....	181	....	1,704
Greeley Canal No. 2	10,996	5,563	4,379	5,158	5,262	1,104	58	38	155	992	847	34,483
Whitney Ditch	778	780	518	260	237	44	....	....	241	950	181	3,989
B. H. Eaton Ditch	200	271	77	30	122	......	....	....	....	414	167	1,281
Jones Ditch	60	130	123	71	104	......	....	....	73	114	2	677
Greeley Canal No. 3	633	360	695	201	441	166	99	....	....	444	351	3,390
Boyd and Freeman Ditch	70	94	105	32	46	10	....	....	17	213	64	651
Ogilvy Ditch	938	308	256	218	538	220	....	....	....	8	24	2,510
Seepage	4,740	3,232	2,440	1,963	1,949	276	41	4	....	923	464	16,032

[1] The acreage here given includes only that under the main canal. The total area irrigated wholly or in part by water of the North Poudre Irrigation Co. (including preferred rights in Fossil Creek Reservoir), was 46,222 acres in 1916 and 50,203 acres in 1917.

[2] Part of the stock of this ditch is owned by the Larimer and Weld Reservoir Co., and the water represented is rented to the Larimer and Weld Irrigation Co. It is taken into the Larimer and Weld Canal through Dry Creek and is applied to all lands under that canal. The area covered by this water is not included here.

[3] The acreage given does not include lands north of Fort Collins irrigated from laterals of the North Poudre Canal with water brought through this canal.

TABLE 10.—*Water, in acre-feet, used by the canals of the valley in 1916.*

DIRECT FLOW.

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.
North Poudre Canal	870	1,760	6,583	4,001	2,245	710	0	16,169
Poudre Valley Canal	0	697	585	486	748	0	0	2,516
Pleasant Valley and Lake Canal	1,357	3,253	4,341	2,977	2,874	1,885	0	16,687
Larimer County Canal	0	5,398	22,147	11,971	8,482	1,878	0	49,876
Jackson Ditch	77	788	1,158	1,305	680	374	0	4,382
Little Cache la Poudre Ditch	0	359	737	1,058	922	0	0	3,076
Taylor and Gill Ditch	365	466	794	786	740	590	276	4,017
Larimer County Canal No. 2	154	3,562	4,455	2,179	691	29	0	11,070
New Mercer Canal	31	2,016	2,147	2,059	1,296	342	0	7,891
Arthur Ditch	491	1,663	1,264	1,703	737	177	79	6,114
Larimer and Weld Canal	1,420	14,704	35,482	10,316	4,439	805	0	67,166
Josh Ames Ditch	28	43	451	576	368	17	0	1,483
Lake Canal	0	4,035	5,116	1,992	304	0	0	11,447
Coy Ditch	0	105	114	366	164	0	0	749
Chaffee Ditch	0	277	64	351	255	0	0	947
Boxelder Ditch	0	514	1,042	948	371	40	0	2,915
Greeley Canal No. 2	1,681	16,431	20,010	11,201	3,136	2,449	0	54,908
Whitney Ditch	109	451	1,086	1,743	1,587	984	64	6,024
B. H. Eaton Ditch	169	277	579	1,115	411	278	0	2,829
Jones Ditch	0	23	312	455	656	94	0	1,540
Greeley Canal No. 3	1,691	2,973	3,958	4,555	3,130	3,215	438	19,960
Boyd and Freeman Ditch	0	0	408	421	382	168	0	1,379
Ogilvy Ditch	720	2,495	2,256	2,197	2,307	1,497	0	11,472
Total	9,163	62,290	115,089	64,761	36,925	15,532	857	304,617

STORAGE.

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.	Grand total.
North Poudre Canal	353	5,337	5,147	10,334	3,331	686	0	25,188	41,357
Poudre Valley Canal	0	0	0	0	0	0	0	0	2,516
Pleasant Valley and Lake Canal	0	0	0	598	206	17	0	821	17,508
Larimer County Canal	0	1,489	1,366	6,310	7,598	5,348	0	22,111	71,987
Jackson Ditch	0	0	0	0	0	0	0	0	4,382
Little Cache la Poudre Ditch	0	0	0	0	0	0	0	0	3,076
Taylor and Gill Ditch	0	0	0	0	0	0	0	0	4,017
Larimer County Canal No. 2	0	0	0	148	64	39	0	251	11,321
New Mercer Canal	0	0	0	0	91	72	0	163	8,054
Arthur Ditch	0	0	0	0	0	23	0	23	6,137
Larimer and Weld Canal	0	0	126	5,432	12,117	6,251	0	23,926	91,092
Josh Ames Ditch	0	0	0	0	0	0	0	0	1,483
Lake Canal	0	0	0	564	1,190	830	0	2,584	14,031
Coy Ditch	0	0	0	0	0	0	0	0	749
Chaffee Ditch	0	0	0	0	0	0	0	0	947
Boxelder Ditch	0	0	0	0	0	0	0	0	2,915
Greeley Canal No. 2	0	0	0	3,169	6,747	3,542	0	13,458	68,366
Whitney Ditch	0	0	0	0	0	0	0	0	6,024
B. H. Eaton Ditch	0	0	0	0	0	0	0	0	2,829
Jones Ditch	0	0	0	0	0	0	0	0	1,540
Greeley Canal No. 3	0	0	0	257	584	409	0	1,250	21,210
Boyd and Freeman Ditch	0	0	0	0	0	0	0	0	1,379
Ogilvy Ditch	0	152	0	286	221	156	0	815	12,287
Total	353	6,978	6,639	27,098	32,149	17,373	0	90,590	395,207

TABLE 11.—*Water in acre-feet used by the canals of the valley in 1917.*

DIRECT FLOW.

	April.	May.	June.	July.	August.	September.	October.	Total.
North Poudre Canal	0	318	8,588	10,069	1,370	400	0	20,745
Poudre Valley Canal	0	0	472	1,165	88	51	0	1,776
Pleasant Valley and Lake Canal	453	202	4,945	6,171	3,119	1,669	0	16,559
Larimer County Canal	0	8,087	22,626	25,386	6,672	1,921	0	64,692
Jackson Ditch	0	86	1,261	1,645	1,079	558	15	4,644
Little Cache la Poudre Ditch [1]	0	0	1,026	505	893	204	0	2,628
Taylor and Gill Ditch	264	231	560	810	784	560	0	3,209
Larimer County Canal No. 2	0	0	4,096	6,795	288	43	0	11,222
New Mercer Canal	0	47	3,075	3,592	1,214	42	0	7,970
Arthur Ditch	0	281	1,495	2,241	453	56	0	4,526
Larimer and Weld Canal [2]	762	2,188	31,957	28,983	2,996	1,003	0	67,889
Josh Ames Ditch	0	0	178	698	532	0	0	1,408
Lake Canal	0	213	5,454	6,156	158	0	0	11,981
Coy Ditch	0	0	0	204	363	41	0	608
Chaffee Ditch	0	0	286	514	198	0	0	998
Boxelder Ditch	0	0	1,272	1,255	1,645	991	0	5,163
Greeley Canal No. 2	0	2,164	18,349	27,132	4,687	1,051	0	53,383
Whitney Ditch	0	0	843	1,478	1,635	997	0	4,953
B. H. Eaton Ditch	0	329	1,071	1,261	989	477	21	4,148
Jones Ditch	0	0	85	29	381	457	0	952
Greeley Canal No. 3	275	946	2,899	4,544	3,170	2,653	0	14,487
Boyd and Freeman Ditch	0	96	134	354	538	254	0	1,376
Ogilvy Ditch	0	686	2,297	3,284	3,212	2,090	11	11,580
Total	1,754	15,874	112,969	134,271	36,464	15,518	47	316,897

STORAGE.

	April.	May.	June.	July.	August.	September.	October.	Total.	Grand total.
North Poudre Canal	0	182	1,250	9,512	13,192	4,818	0	28,954	49,699
Poudre Valley Canal	0	0	0	0	0	0	0	0	1,776
Pleasant Valley and Lake Canal	0	0	0	0	376	276	0	652	17,211
Larimer County Canal	0	0	1,108	2,511	13,883	1,772	0	19,274	83,966
Jackson Ditch	0	0	0	0	0	0	0	0	4,644
Little Cache la Poudre Ditch [1]	0	0	0	0	0	0	0	0	2,628
Taylor and Gill Ditch	0	0	0	0	0	0	0	0	3,209
Larimer County Canal No. 2	0	0	0	0	108	78	0	186	11,408
New Mercer Canal	0	0	0	0	0	191	0	191	8,161
Arthur Ditch	0	0	0	0	0	17	0	17	4,543
Larimer and Weld Canal [2]	0	0	0	1,607	20,676	7,264	0	29,547	97,436
Josh Ames Ditch	0	0	0	0	0	0	0	0	1,408
Lake Canal	0	0	0	0	1,538	510	0	2,048	14,029
Coy Ditch	0	0	0	0	0	0	0	0	608
Chaffee Ditch	0	0	0	0	0	0	0	0	998
Boxelder Ditch	0	0	0	0	0	0	0	0	5,163
Greeley Canal No. 2	0	0	0	0	9,141	5,476	0	14,617	68,000
Whitney Ditch	0	0	0	0	0	0	0	0	4,953
B. H. Eaton Ditch	0	0	0	0	0	0	0	0	4,148
Jones Ditch	0	0	0	0	0	0	0	0	952
Greeley Canal No. 3	0	0	0	0	1,021	393	0	1,414	15,901
Boyd and Freeman Ditch	0	0	0	0	0	0	0	0	1,376
Ogilvy Ditch	0	0	0	83	289	95	0	467	12,047
Total	0	182	2,358	13,713	60,224	20,890	0	97,367	414,264

[1] Use under Little Cache la Poudre does not include amount delivered to Dry Creek on rights owned by Larimer & Weld Reservoir Co.
[2] Reservoir water used in July by Larimer and Weld Canal was advanced to canal by Windsor Reservoir to be paid from direct flow later.

The gross duty for the canals of the valley by months and for the year, for both direct flow and storage as shown in Tables 12 and 13, is derived from Tables 9, 10, and 11. The lowest duty is shown by the ditches with old rights watering the bottoms along the river. However, a considerable part of the water carried by them is wasted directly back into the river by laterals and the actual require-

ments of the land under them are much less than the duty shown would indicate. The apparent high duty under the North Poudre Canal in 1916 was due to a short supply, the original allotment of 125,000 cubic feet per share for that year being reduced to 100,000 cubic feet in the latter part of the season. In the majority of cases, however, the duty fairly indicates the requirements of the land under the canal under the present system of cropping.

TABLE 12.—*Monthly and annual gross duty of water in acre-feet per acre under canals of the valley in 1916.*

DIRECT FLOW.

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total
North Poudre Canal	0.03	0.06	0.22	0.14	0.08	0.02	0.00	0.55
Poudre Valley Canal	.00	1.05	.88	.73	1.12	.00	.00	3.78
Pleasant Valley & Lake Canal	.20	.47	.63	.43	.42	.27	.00	2.41
Larimer County Canal	.00	.11	.47	.25	.18	.04	.00	1.06
Jackson Ditch	.03	.35	.51	.58	.30	.17	.00	1.94
Little Cache la Poudre Ditch	.00	.23	.47	.67	.59	.00	.00	1.96
Taylor and Gill Ditch	.86	1.10	1.88	1.86	1.75	1.39	.65	9.50
Larimer County Canal No. 2	.02	.54	.68	.33	.10	.00+	.00	1.68
New Mercer Canal	.01	.39	.41	.40	.25	.07	.00	1.52
Arthur Ditch	.22	.74	.56	.76	.33	.08	.04	2.72
Larimer and Weld Canal	.03	.26	.63	.18	.08	.01	.00	1.20
Josh Ames Ditch	.03	.04	.46	.58	.37	.02	.00	1.50
Lake Canal	.00	.55	.70	.27	.04	.00	.00	1.56
Coy Ditch	.00	.47	.51	1.65	.74	.00	.00	3.37
Chaffee Ditch	.00	.61	.14	.77	.56	.00	.00	2.09
Boxelder Ditch	.00	.30	.61	.56	.22	.02	.00	1.71
Greeley Canal No. 2	.05	.48	.59	.33	.09	.07	.00	1.62
Whitney Ditch	.03	.12	.28	.45	.41	.25	.02	1.54
B. H. Eaton Ditch	.13	.21	.45	.86	.32	.22	.00	2.19
Jones Ditch	.00	.03	.46	.67	.97	.14	.00	2.27
Greeley Canal No. 3	.49	.87	1.15	1.33	.91	.94	.13	5.82
Boyd and Freeman Ditch	.00	.00	.67	.69	.63	.28	.00	2.26
Ogilvy Ditch	.29	1.01	.91	.89	.93	.60	.00	4.62
Average[1]	.04	.30	.55	.31	.18	.07	.00+	1.45

[1] Based on a total area of approximately 210,000 acres irrigated by the canals listed.

STORED WATER.

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.	Grand total.
North Poudre Canal	0.01	0.18	0.17	0.35	0.11	0.02	0.00	0.85	1.40
Poudre Valley Canal	.00	.00	.00	.00	.00	.00	.00	.00	3.78
Pleasant Valley & Lake Canal	.00	.00	.00	.09	.03	.00+	.00	.12	2.53
Larimer County Canal	.00	.03	.03	.13	.16	.11	.00	.47	1.53
Jackson Ditch	.00	.00	.00	.00	.00	.00	.00	.00	1.94
Little Cache la Poudre Ditch	.00	.00	.00	.00	.00	.00	.00	.00	1.96
Taylor and Gill Ditch	.00	.00	.00	.00	.00	.00	.00	.00	9.50
Larimer County Canal No. 2	.00	.00	.00	.02	.01–	.01–	.00	.04	1.72
New Mercer Canal	.00	.00	.00	.00	.02	.01	.00	.03	1.55
Arthur Ditch	.00	.00	.00	.00	.00	.01	.00	.01	2.73
Larimer and Weld Canal	.00	.00	.00+	.10	.22	.11	.00	.43	1.63
Josh Ames Ditch	.00	.00	.00	.00	.00	.00	.00	.00	1.50
Lake Canal	.00	.00	.00	.08	.16	.11	.00	.35	1.92
Coy Ditch	.00	.00	.00	.00	.00	.00	.00	.00	3.37
Chaffee Ditch	.00	.00	.00	.00	.00	.00	.00	.00	2.09
Boxelder Ditch	.00	.00	.00	.00	.00	.00	.00	.00	1.71
Greeley Canal No. 2	.00	.00	.00	.09	.20	.10	.00	.40	2.01
Whitney Ditch	.00	.00	.00	.00	.00	.00	.00	.00	1.54
B. H. Eaton Ditch	.00	.00	.00	.00	.00	.00	.00	.00	2.19
Jones Ditch	.00	.00	.00	.00	.00	.00	.00	.00	2.27
Greeley Canal No. 3	.00	.00	.00	.07	.17	.12	.00	.36	6.19
Boyd and Freeman Ditch	.00	.00	.00	.00	.00	.00	.00	.00	2.26
Ogilvy Ditch	.00	.06	.00	.12	.09	.06	.00	.33	4.95
Average[1]	.00	.03	.03	.13	.15	.08	.00	.43	1.88

[1] Based on a total area of approximately 210,000 acres irrigated by the canals listed.

TABLE 13.—*Monthly and annual gross duty of water in acre-feet per acre under canals of the valley in 1917.*

DIRECT FLOW.

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.
North Poudre Canal	0	0.01	0.26	0.30	0.04	0.01	0	0.62
Poudre Valley Canal	0	0	.71	1.75	.13	.08	0	2.67
Pleasant Valley and Lake Canal	0.06	.03	.67	.84	.42	.23	0	2.26
Larimer County Canal	0	.17	.47	.53	.14.	.04	0	1.35
Jackson Ditch	0	.04	.56	.73	.48	.25	0.01	2.05
Little Cache la Poudre Ditch	0	0	.66	.33	.58	.13	0	1.70
Taylor and Gill Ditch	.62	.55	1.32	1.91	1.85	1.32	0	7.59
Larimer County Canal No. 2	0	0	.62	1.02	.04	.01	0	1.69
New Mercer Canal	0	.01	.59	.69	.23	.01	0	1.52
Arthur Ditch	0	.12	.64	.96	.19	.02	0	1.94
Larimer and Weld Canal	.01	.04	.55	.50	.05	.02	0	1.17
Josh Ames Ditch	0	0	.19	.74	.57	0	0	1.50
Lake Canal	0	.03	.77	.87	.02	0	0	1.69
Coy Ditch	0	0	0	.91	1.63	.18	0	2.73
Chaffee Ditch	0	0	.63	1.13	.44	0	0	2.20
Boxelder Ditch	0	0	.75	.74	.97	.58	0	3.03
Greeley Canal No. 2	0	.06	.53	.79	.14	.03	0	1.55
Whitney Ditch	0	0	.21	.37	.41	.25	0	1.24
B. H. Eaton Ditch	0	.26	.84	.98	.77	.37	.02	3.24
Jones Ditch	0	0	.13	.04	.56	.68	0	1.41
Greeley Canal No. 3	.08	.28	.86	1.34	.94	.78	0	4.27
Boyd and Freeman Ditch	0	.15	.21	.54	.83	.39	0	2.11
Ogilvy Ditch	0	.27	.92	1.31	1.28	.83	0	4.61
Average [1]	.01	.07	.52	.62	.17	.07	0	1.46

STORED WATER.

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.	Grand total.
North Poudre Canal	0	0.01	0.04	0.28	0.39	0.14	0	0.86	1.48
Poudre Valley Canal	0	0	0	0	0	0	0	0	2.67
Pleasant Valley and Lake Canal	0	0	0	0	.05	.04	0	.09	2.34
Larimer County Canal	0	0	.02	.05	.29	.04	0	.40	1.76
Jackson Ditch	0	0	0	0	0	0	0	0	2.05
Little Cache la Poudre Ditch	0	0	0	0	0	0	0	0	1.70
Taylor and Gill Ditch	0	0	0	0	0	0	0	0	7.59
Larimer County Canal No. 2	0	0	0	0	.02	.01	0	.03	1.71
New Mercer Canal	0	0	0	0	0	.04	0	.04	1.56
Arthur Ditch	0	0	0	0	0	.01	0	.01	1.95
Larimer and Weld Canal	0	0	0	.03	.35	.13	0	.51	1.68
Josh Ames Ditch	0	0	0	0	0	0	0	0	1.50
Lake Canal	0	0	0	0	.22	.07	0	.29	1.98
Coy Ditch	0	0	0	0	0	0	0	0	2.73
Chaffee Ditch	0	0	0	0	0	0	0	0	2.20
Boxelder Ditch	0	0	0	0	0	0	0	0	3.03
Greeley Canal No. 2	0	0	0	0	.27	.16	0	.42	1.97
Whitney Ditch	0	0	0	0	0	0	0	0	1.24
B. H. Eaton Ditch	0	0	0	0	0	0	0	0	3.24
Jones Ditch	0	0	0	0	0	0	0	0	1.41
Greeley Canal No. 3	0	0	0	0	.30	.12	0	.42	4.69
Boyd and Freeman Ditch	0	0	0	0	0	0	0	0	2.11
Ogilvy Ditch	0	0	0	.03	.12	.04	0	.19	4.80
Average [1]	0	0	.01	.06	.28	.10	0	.45	1.91

[1] Based on a total area of approximately 217,000 acres irrigated by the canals listed.

TABLE 14.—*Duty measured at the heads of laterals.*

1916.

Lateral.	Canal.	Days run.	Acres irrigated.	Acre-feet used.	Acre-feet per acre.	Acre-feet per acre, entire canal.	Ratio.
Cactus Hill	North Poudre Canal						
No. 2 Outlet	do	129	2,935	2,745	0 93	1.40	66
Crane	Larimer County Canal	81	1,219	1,273	1.04	1.53	67
Crosscut	do	104	2,170	3,791	1.75	1.53	114
Bliss	Pierce Lateral of Larimer County Canal	105	1,123	1,151	1.03	1.53	67
	Jackson	126	444	1,128	2.54	1.94	131
Mitchell	Little Cache la Poudre	28	129	79	.61	1.96	31
Dixon Canyon	Larimer County Canal, No. 2						
Town	Larimer and Weld Canal	106	4,092	7,678	1.87	1.63	115
	Lake Canal						
Total and average.			12,112	17,845	1.47	1.58	93

1917.

Lateral.	Canal.	Days run.	Acres irrigated.	Acre-feet used.	Acre-feet per acre.	Acre-feet per acre, entire canal.	Ratio.
Cactus Hill	North Poudre Canal	108	1,870	2,667	1.43	1.48	97
No. 2 Outlet	do	110	2,935	3,579	1.22	1.48	82
Crane	Larimer County Canal	106	1,210	1,850	1.53	1.76	87
Crosscut	do	115	2,169	4,634	2.12	1.76	120
Bliss	Pierce Lateral of Larimer County Canal	115	1,163	2,017	1.73	1.76	98
	Jackson	113	444	1,233	2.78	2.05	136
Mitchell	Little Cache la Poudre	27	83	58	.70	1.70	41
Dixon Canyon	Larimer County Canal, No. 2	44	1,066	1,484	1.39	1.71	81
Town	Larimer and Weld Canal	105	4,166	9,519	2.29	1.68	136
	Lake Canal	74	575	1,234	2.15	1.98	109
Total and average.			15,681	28,275	1.80	1.68	107

DUTY AT HEADS OF LATERALS.

During the investigation, records of discharge and acreage irrigated were obtained for a number of laterals to afford a comparison of the duty measured at the head of the lateral with the duty measured at the head of the canal. The results of the measurements, together with the comparisons, are shown in Table 14. These erratic variations may be occasioned by a number of conditions. There are no restrictions on holdings of shares of ditch stock with reference to the acreage irrigated, and under a single lateral the ratio between the two may be as much as 20 per cent above or below the average ratio for the entire canal. Such a lateral would be entitled on its shares to an amount of water 20 per cent above the average for the entire canal. What is true of canal shares is true to a greater degree of reservoir rights carried in the canals which act as common carriers, for water from this source is limited only by the number of rights which can not be bought, rented, or borrowed. A considerable part of the variation may be attributed to systems of distribution to laterals. A few of the canals, including the Little Cache la Poudre and the Jackson ditches, have no measuring devices for distribution

and depend on the judgment of the rider to make a fair division. No man's judgment is infallible, and it is to be expected that considerable errors must result. Even where weirs are used the installation is often faulty enough to produce a difference of 25 per cent between the amount supposed to be delivered and the amount actually delivered. In addition the kinds of crops grown no doubt account for some of the variation. Because of high prices and war needs the acreage of potatoes under 2 or 3 laterals in 1917 was increased at a much greater rate than for the entire canal. This resulted in a proportionately lower duty for the lateral. Under other laterals the switch was from alfalfa to wheat, and in these cases the duty was correspondingly higher.

ABSORPTION LOSSES IN CANALS.

Conditions are such in the Cache la Poudre Valley that there are few canals in which sections suitable for measuring absorption losses may be found. The quantities to be determined are small and the methods of measurement have their limitations, so conditions are best when the loss may be determined for a uniform head for a long period over a stretch of canal into which there is no drainage and from which there is no outflow. Almost without exception, distributing canals could not be used on account of the many diversions, beginning almost at the headgate. Canals carrying water for storage were usually unsatisfactory on account of fluctuating heads, uncertain supply, or ice conditions. However, fairly satisfactory measurements were obtained on the Poudre Valley, North Poudre, and Larimer and Weld Canals.

The measurement on the Poudre Valley Canal was made in the latter part of May, 1917, and included a section of the canal from the head to a station a short distance above the Dry Creek crossing, a distance of 10.6 miles. For the 36-hour period observed, the average flow at the upper station was 232.4 second-feet and at the lower station 220.0 second-feet, giving a total loss of 12.4 second-feet. This is equivalent to 1.17 second-feet per mile or 0.5 per cent of the total flow. Expressed in different terms, the loss per day per square foot of wetted area was 0.41 cubic foot.

The measurement of the North Poudre Canal was made from July 6 to 9, 1916, and covered a period of 58 hours. The section included extended from the rating station at the head of the canal to a station near Waverly, a distance of approximately 16 miles. During the observation there was a small inflow from Reservoir No. 15 and from a small spring a mile above the mouth of Camp-

bells Draw. Diversions included a small amount delivered to the Ripple ranch and a large head taken by the Scurvin Ditch. The average discharge at the head was 172 second-feet and the loss was 20.6 second-feet. This is at the rate of 1.29 second-feet per mile or 0.75 per cent of the total flow. The section measured includes a stretch of natural channel and for that reason the loss per square foot of wetted area can not be determined with any degree of accuracy.

Two measurements were secured on the Larimer and Weld Canal in 1917 while water was being carried for storage in the Windsor Reservoir. The section measured included a stretch 12 miles long with a 30-foot bottom between the head of the canal and Lake Lee. The first observation included a period of 12 days between March 29 and April 9 when the average discharge at the head of the canal was 63 second-feet. The loss during the period was 0.92 second-foot per mile or 1.5 per cent of the total flow which is equivalent to a loss of 0.81 cubic foot per day per square foot of wetted area. The second measurement included a period of 14 days between May 2 and 16 when the average discharge at the head was 242 second-feet. During this period this loss was 1.33 second-feet per mile or 0.5 per cent of the total flow which is equivalent to a loss of 0.64 cubic foot per day per square foot of wetted area.

When the investigation was undertaken it was believed that the difference between the duty at the head of canals and the duty at the head of representative laterals would give a fair approximation of the average loss in main canals and that the difference between the duty at the head of the lateral and at the farm would give the approximate loss in the laterals. On this assumption, if the averages shown in Table 14 are applicable to the entire valley, there was in main canals in 1916 a loss of 7 per cent and in 1917 a gain of 7 per cent. However, the data shown in the table are too meager to warrant the acceptance of these figures, but similar results are obtained by comparing the duty at the farm with the duty at the head of canals. In Tables 10 and 11 the total supply of water of the canals listed is shown to have been 395,000 acre-feet in 1916 and 414,000 acre-feet in 1917. By applying to the acreage of the various crops the figures representing duties, the majority of which are shown in Tables 9 to 14 and 18 to 27 it is possible to determine the total demand for each year under the canals listed. Duties for corn, peas, and other crops occupying less than 10 per cent of the acreage may be estimated without introducing a considerable error. The demand for 1916 determined in this manner was 354,000 acre-feet and to satisfy this demand there was a supply of 395,000 acre-feet, the

difference indicating a loss of 41,000 acre-feet, or approximately 10 per cent of the supply. In 1917 a demand of 435,000 acre-feet determined in a like manner was satisfied with a supply of 414,000 acre-feet, the difference indicating a gain of approximately 5 per cent. In view of the heavy rainfall of May, 1917, and the very large heads carried by all the canals in June and July of that year, it is believed that these approximations are in substantial accord with the facts. Conditions in 1916 were nearly normal and for that reason the assumption may be safely made that the average net loss in the canals between the head and the farm lateral is close to 10 per cent of the supply. This low figure is probably accounted for by the location of the canals one above another with the consequent inflow of seepage to counteract a part of the loss.

These figures indicate that absorption losses account for only a small part of the tare for losses charged by some of the common-carrier canals of the valley, and that most of it must go to make up inequalities of distribution. Under the present system each user receives at least his share after the tare has been deducted; but to take care of the inequalities of distribution and operation difficulties there is practically always a surplus in the canal which must go to some one to prevent its waste. It is possible that by spending a few thousand dollars for hire of extra riders and reducing the "beat" to a distance which will permit 2 or 3 visits every day to all gates and weirs to keep them clean and delivering the proper head, at least one day's run and perhaps two or three might be added each season to each reservoir right.

SEEPAGE SUPPLIES.

Practically the entire acreage irrigated in the valley is supplied to some extent with seepage water which has been collected in a reservoir or has returned to some channel, but the land dependent on seepage as its main supply is limited to the areas shown in Plate XIV.

FARM IRRIGATION.

While there are some exceptions, the trend of irrigation practice in the valley now is toward a frequent, rapid irrigation, which gives an even watering, minimizes percolation losses and end waste, permits the use of a large head with a consequent economy of time, and keeps the crops growing under moisture conditions with a minimum variation from the optimum.

Only two methods of irrigation are practiced. Alfalfa and grains are irrigated by flooding from field laterals. Sugar beets, potatoes,

and other row crops are irrigated by furrows between the rows. The method of flooding from field laterals, used on nearly two-thirds of the total irrigated area of the valley, does not vary essentially from the general practice. Supply ditches are located at the margin of the field; small laterals from these extend into the field; and through openings in these field laterals the water flows out over the land. In general, the effort is so to fit the layout of the supply ditches and field laterals to conditions of soil and topography that with a head

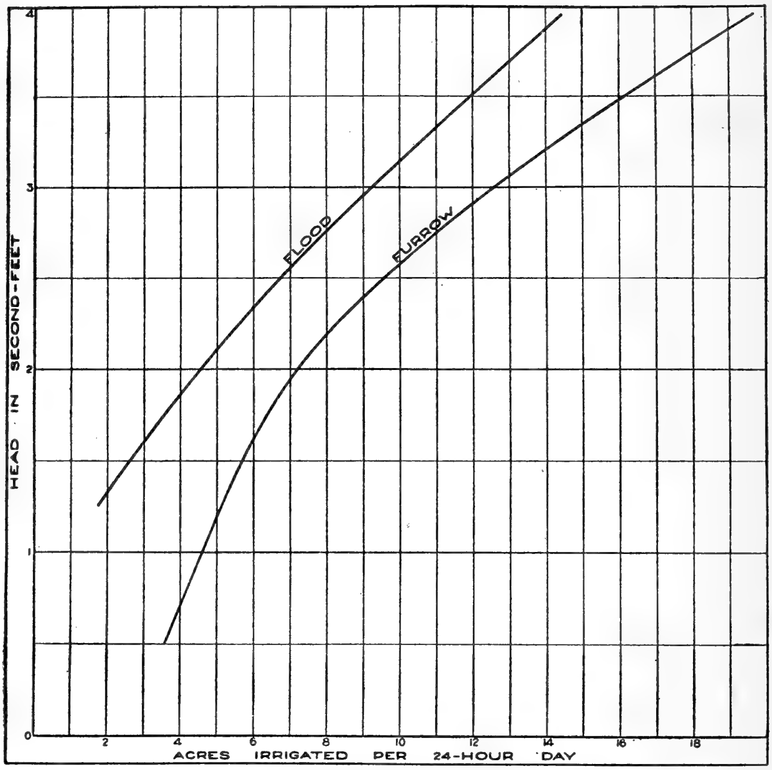


FIG. 4.—Relation between the head used and the area irrigated per 24-hour day for flood and furrow irrigation.

of from 2 to 3 second-feet a thorough irrigation may be secured with a minimum expenditure of time and work. For this reason the details of practice vary almost with the number of fields.

Supply ditches are carried along the margin of the field or follow ridges, the former location being preferred if conditions are at all suitable as less space is required and cultivating and harvesting may be carried on with less difficulty. Practically all these ditches are

equipped with concrete or wooden turnouts to supply the field laterals. For alfalfa the field laterals are permanent, but for annual crops they are made each spring with a ditching plow, and after irrigation is completed they are plowed flat again so that harvesting machinery

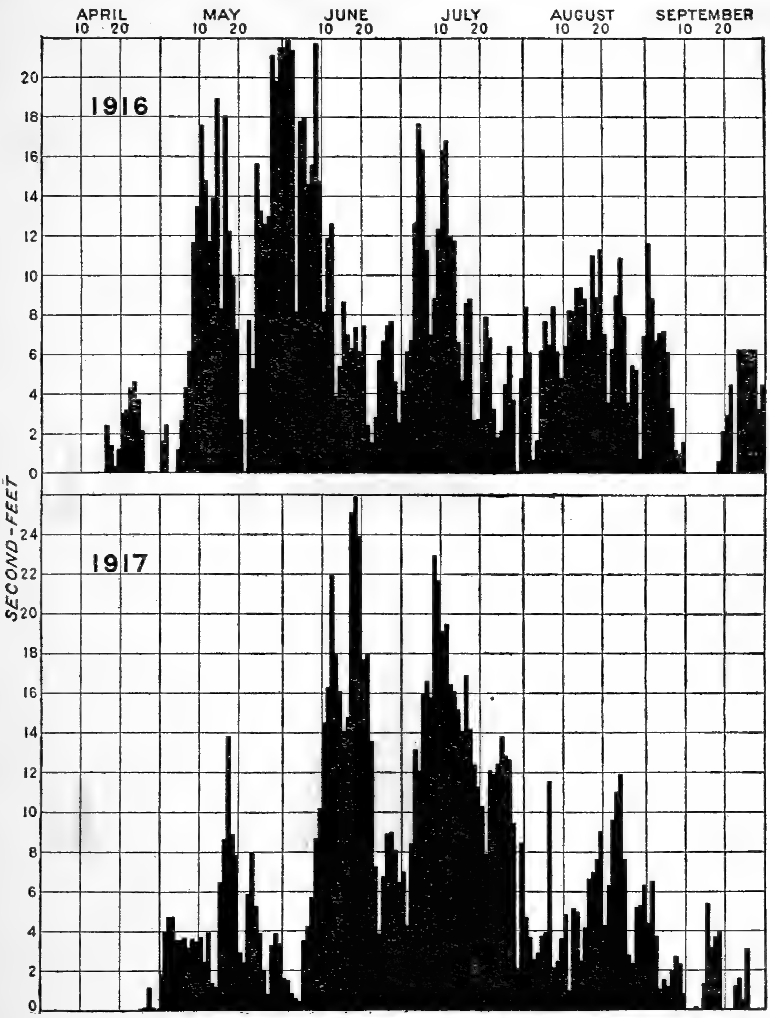


FIG. 5.—Irrigation of alfalfa. Water requirements of 988 acres in 1916 and of 686 acres in 1917.

may pass over them without difficulty. If the field to be irrigated is smooth and has a uniform slope, the field laterals are made parallel, 75 to 200 feet apart, and oblique to the main slope of the land. In this case the water from one lateral irrigates the field down to the

next. If the land is rolling, the laterals are spaced to follow the ridges and water is turned down both slopes. On very uneven land it is customary to build the field laterals to high points where the water is turned out to be directed here and there by temporary dikes thrown up with a shovel. To get the water from the lateral to the field cuts are made in the banks at intervals of from 5 to 20 feet and the water is forced through by checking the lateral farther down with a canvas, metal, or dirt dam.

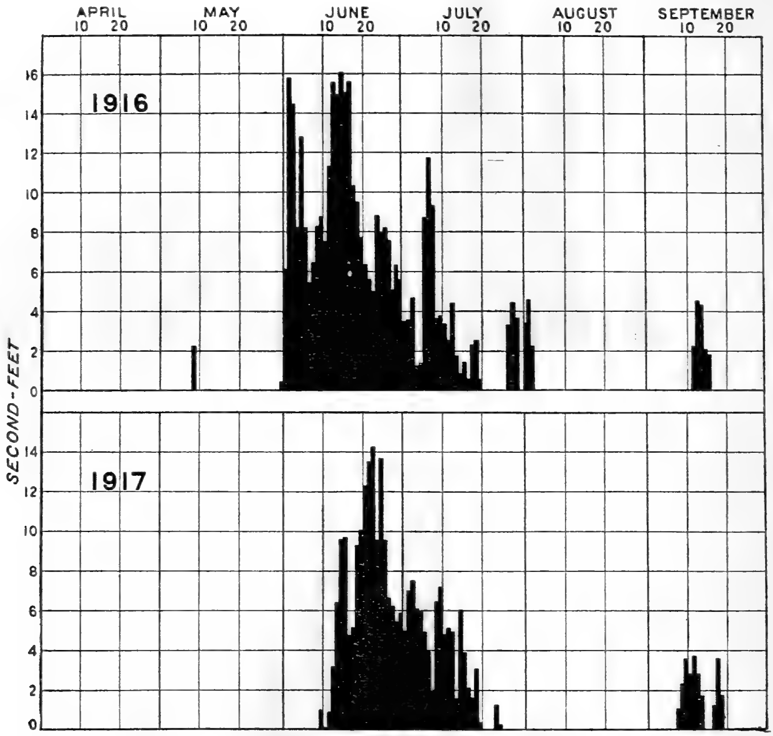


FIG. 6.—Irrigation of grain. Water requirements of 622 acres in 1916 and of 429 acres in 1917.

By far the greater part of the area irrigated by the furrow method is in sugar beets and potatoes, but corn, beans, peas, and truck are also irrigated in this manner. In the valley irrigation by this method consists in plowing furrows between the rows and running water down these furrows from notches cut in a ditch at the head of the field. Furrows are made in each middle with a shovel or other suitable plow and are especially deep for potatoes. To secure an even, fast irrigation, furrows are usually about 500 feet long, but the type of soil, slope of land, and amount of water available will cause a wide

variation in this particular. The general practice is to run water in each furrow, but some farmers use every other furrow and altenate for each irrigation the set used. Permanent head ditches are often fitted with concrete or wooden checks to hold the water up to the notches cut in the bank; otherwise canvas or metal dams are used. Where head ditches are necessary in the middle of a field they are

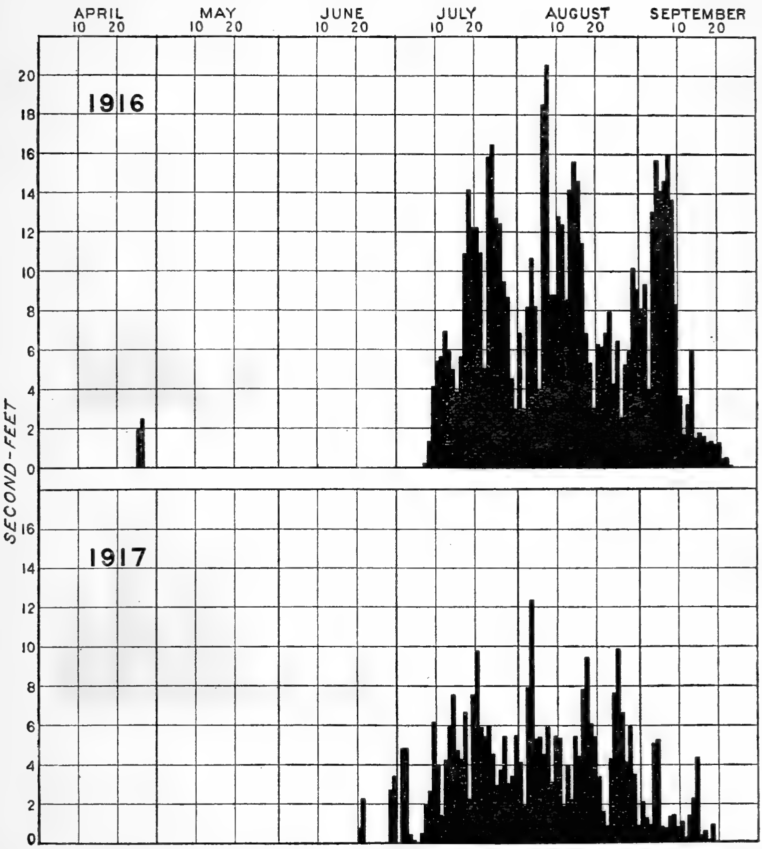


FIG. 7.—Irrigation of sugar beets. Water requirements of 584 acres in 1916 and 376 acres in 1917.

plowed out in the usual manner and dragged with a "V" to smooth and pack the sides. For turning the water from the head ditch to the furrows a notch may be made for each furrow or the water from a single cut may supply several furrows.

Under small canals with good water rights, when the farmer finishes his day of irrigating he goes to the head of his supply ditch and cuts off the water there for the night. But under large canals

conditions are different and when water is plentiful the safe operation of the canal requires that the user take his supply of water from the canal day and night until he orders it cut off by the ditch rider. When water is scarce the user takes it eagerly, day or night. It is necessity in these forms, rather than any virtue in its practice in the Cache la Poudre Valley, which is responsible for night irrigation there. Row crops are not often irrigated at night and matters are usually so arranged that the supply may be turned for the night on alfalfa or pasture land where a small excess of water will do no harm.

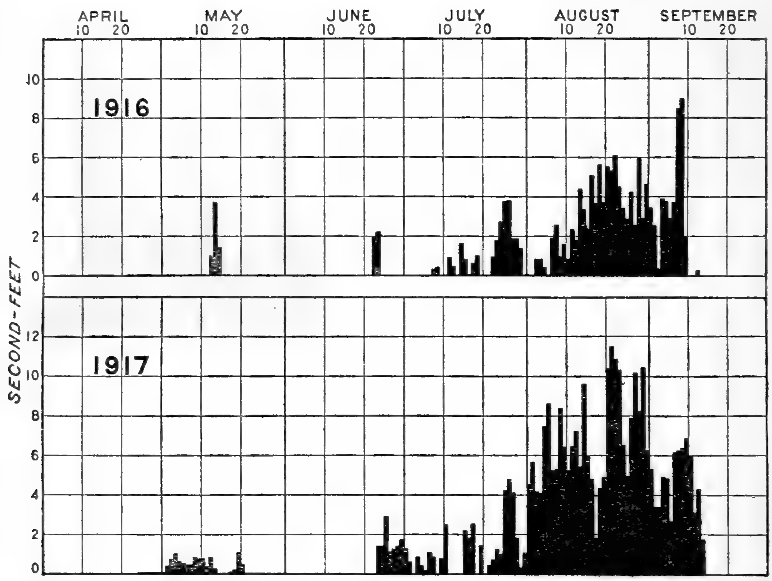


FIG. 8.—Irrigation of potatoes. Water requirements of 157 acres in 1916 and 285 acres in 1917.

It is seldom possible to apply enough water to a field for a uniform, thorough irrigation without having a certain run-off at the lower end. The amount of this run-off was determined for a number of fields of alfalfa and grain and was found to range from 2 to 18 per cent, with an average slightly under 6 per cent. In the majority of cases this can be called waste only with reference to the particular field from which it comes as the general practice is to collect it in ditches and use it on lower fields.

In figure 4 the relation between the head used and the area irrigated per 24-hour day is shown by curves for both flood and furrow irrigation. The curve for flood irrigation is based on 284 irrigations of fields of alfalfa and grain, while the curve for furrow irri-

gation is based on 324 irrigations of sugar beets, potatoes, and other row crops. The location and trend of the curve for furrow irrigation is influenced to a great extent by very rapid, alternate, furrow irrigation as practiced frequently on many of the farms of the valley.

In order to secure reliable data on farm irrigation a careful record was kept of the water used on about 25 farms during the period of the investigation. These farms were selected at widely scattered points and represent fairly the various conditions of soil, water rights, and irrigation practice encountered in the valley. In Table 15 each farm is listed with its location, general type of soil, and the kinds of water with which it is supplied.

TABLE 15.—*Farms selected for the investigation of farm irrigation.*

Farm.	Location.			Soil.	Water.
	Section.	Township.	Range.		
R. D. Hughes	20	7	65	Fine sandy loam	Larimer & Weld Canal, Windsor Reservoir, Terry Lake; pumped from canal.
Wilson-Campbell	36	7	66	do	Larimer & Weld Canal, Windsor Reservoir, Terry Lake.
John A. Mair	10	7	68	do	Larimer & Weld Canal (No. 10 right).
C. A. Bartels	28	8	68	do	Larimer County Canal (stored in Clark Lake.)
C. A. Culver	28	8	68	do	Do.
Shafer-Haines	27	8	66	do	Pierce lateral of Larimer County Canal.
Shafer-Uhrick	27	8	66	do	Do.
Farmers' National Bank-Page.	13	7	66	Loam and fine sandy loam.	Larimer County Canal.
Carpenter-McMurray	30	6	63	Fine sandy loam	Greeley Canal, No. 2, Greeley-Poudre water.
Carpenter-Lyning	30	6	63	do	Do.
Charles F. Mason	20	6	65	Loam and fine sandy loam.	Greeley Canal, No. 2, Cache la Poudre Reservoir, Fossil Creek Reservoir.
Jackson-Alles	15	5	65	Fine sandy loam	Greeley Canal, No. 3.
C. A. Johnson	14	6	68	Loam and silty loam	Fossil Creek Reservoir.
Charles and Henry Rassmussen.	6	5	64	Adobe and sandy loam	Ogilvy Ditch.
M. W. Dealy	21	8	69	Fine sandy loam	Jackson Ditch water stored in Dealy Reservoir through Larimer County Canal.
Jacob Ruff	22	8	69	do	Jackson Ditch water through Larimer County Canal.
H. R. Mitchell	34	8	69	Loam and sandy loam.	Little Cache la Poudre Ditch.
A. L. Bee	10	8	68	Sandy loam, loam, and silt loam.	North Poudre Canal; pumped well.
Frank Wells	17	7	67	Fine sandy loam	North Poudre Canal.
Frank J. Earle	34	8	68	Fine sandy loam and silt loam.	Boxelder Creek.
C. A. Duncan	36	7	68	Fine sandy loam	Lake Canal, Cache la Poudre Reservoir, Gray Reservoir.
John Stroh	34	7	68	Sandy loam	Boxelder Ditch.
Michie Bros	35	7	69	Gravelly loam	Pleasant Valley and Lake Canal, North Poudre Canal by exchange.
Fred Wells	24	7	69	Loam	Arthur Ditch.
Minor-Wilson	27	7	65	Loam and clay loam	Pumped well.
Minor-Miller	27	7	65	do	Do.
Wilson-Bass	27	7	65	do	Do.

In Table 16 is given a general summary of all records of farm irrigation with the exception of those covering small areas of corn, peas, and other crops. The average head used may be taken as the head handled by one man, as only in a few cases were two men employed in irrigating a single field. The ratio of hours water was

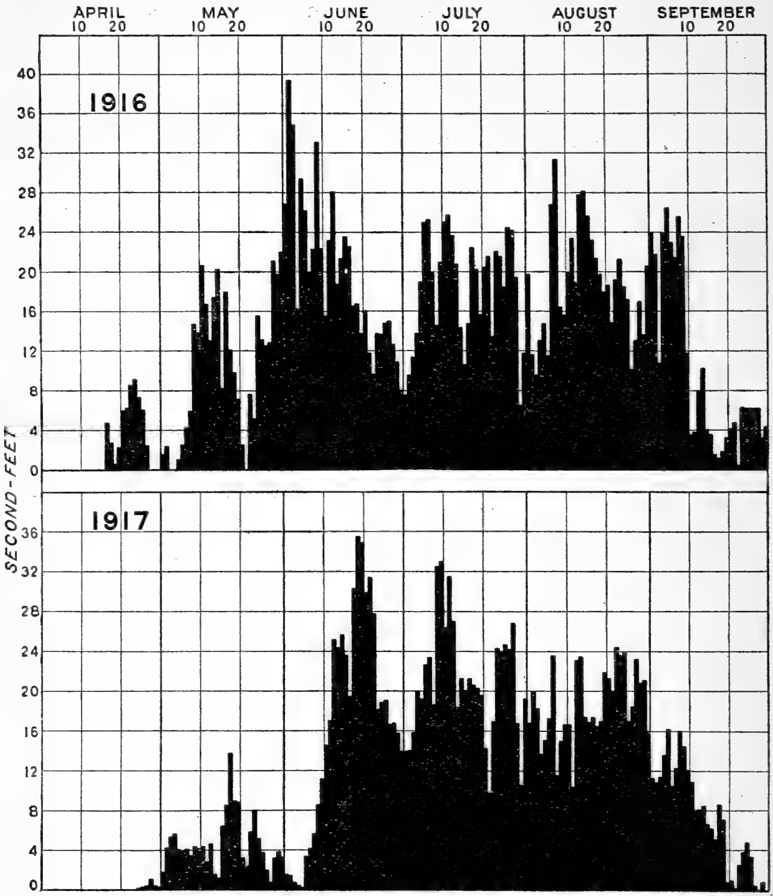


FIG. 9.—Water requirements of 2,500 acres of miscellaneous crops in 1916 and of 2,000 acres in 1917.

attended to hours it was run is lowered considerably by night irrigation, and with this eliminated the ratio would probably be from 80 to 90 for most of the crops. One of the farms for which duties were determined, the Jackson-Alles farm, is located on the delta between the Cache la Poudre and the South Platte, where the soil

is a nonretentive, very fine, sandy loam, underlain by coarse material which permits a very rapid drainage. This condition and the excellent water rights of the Greeley Canal No. 3 account for the very low duty of nearly 17 acre-feet per acre for potatoes on the farm. Charles F. Mason on his farm near Greeley frequently practices a very rapid light irrigation in alternate furrows and is enabled by this method to cover a very large acreage per day. In July, 1916, with a head of 3.75 second-feet a field of 8.1 acres of beans was irrigated in 4½ hours, or at the rate of 43 acres per day. High duties are in most cases accounted for by good irrigation practice, but in a few cases the cost of pumping, a scarcity of water, or a high ground-water table is responsible.

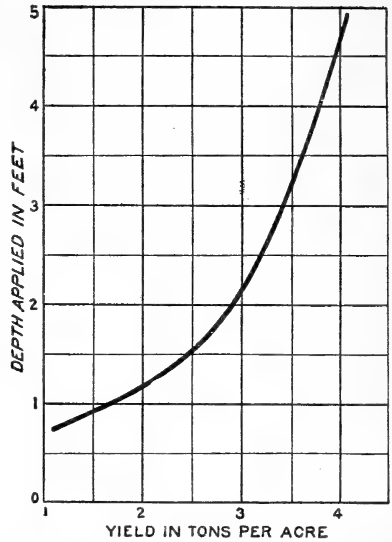


Fig. 10.—Irrigation of alfalfa. Relation between the depth of water applied and the yield.

Dates of irrigations varied widely with conditions, such as type of soil, depth to water table, rainfall, date of planting, water supply, and others. The greatest range noted was a difference of 90 days between the earliest and latest first irrigation of alfalfa, the dates being April 17 and July 16. In Table 17 are given the average irrigation dates for the principal crop in 1916, a normal year, which were obtained by giving the date of the beginning of the irrigation its proper number as a day of the year and then averaging these numbers

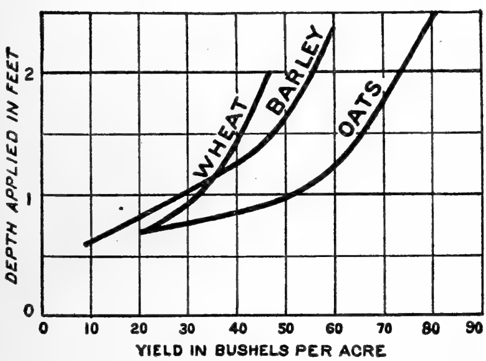


Fig. 11.—Irrigation of grain. Relation between the depth of water applied and the yield.

TABLE 16.—*Summary of records of the irrigation of crops in the Cache La Poudre Valley in 1916 and 1917.*

Crop.	Number of fields.	Total area of fields (acres).	Number of irrigations.			Size of head used (second-feet).			Ratio of hours attended to hours run.		
			Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
Alfalfa	74	1,674	3.02	7	1	2.59	7.78	0.58	0.57	1.00	0.04
Wheat	26	491	1.21	2	1	2.23	4.59	1.16	.56	.88	.22
Oats	15	196	1.64	4	1	2.25	5.20	1.21	.62	1.00	.33
Barley	31	364	1.27	3	1	2.10	5.22	.99	.62	1.00	.16
Sugar beets	61	960	2.90	5	1	1.85	4.47	.52	.71	1.00	.46
Potatoes	38	442	3.79	6	2	1.99	3.70	.55	.68	1.00	.40
Beans	18	225	2.69	5	2	2.02	3.17	1.21	.80	1.00	.55

Crop.	Number of acres irrigated per day.			Depth of water applied (feet).			Average yield per acre.
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	
Alfalfa	6.02	19.52	1.55	2.57	13.59	0.52	2.75 tons.
Wheat	5.13	17.54	2.22	1.04	2.81	.17	27.75 bushels.
Oats	5.43	12.02	1.61	1.35	3.07	.60	48.06 bushels.
Barley	4.45	31.04	1.39	1.19	3.96	.14	40.73 bushels.
Sugar beets	5.70	24.72	1.75	1.86	6.59	.32	12.56 tons.
Potatoes	6.78	22.27	1.51	2.20	16.94	.74	230.07 bushels
Beans	15.63	54.80	6.72	.69	1.06	.34	22.75 bushels.

TABLE 17.—*Average dates of irrigation.*

Crop.	First.	Second.	Third.	Fourth.	Fifth.	Sixth.
Alfalfa	May 25	July 8	Aug. 3	Aug. 17	Aug. 8	....
Grain	June 16	June 25	July 9	....	....	....
Sugar beets	July 19	Aug. 14	Aug. 31	Sept. 5	Sept. 2	....
Potatoes	July 30	Aug. 15	Aug. 18	Aug. 21	Aug. 24	Sept. 8
Beans	June 24	July 27	July 24	Aug. 14	....	....

In figures 5 to 8 the distribution of the demand throughout the season is shown for the acreage in the principal crops on the farms selected for the investigation of farm irrigation. Figure 9 shows the combined demand of all the crops on these farms each year.

It will be noticed by reference to figure 1 that 5 inches, or more than one-third of the average annual rainfall, occurs in April and May. For this reason it usually happens that the crops have a natural start and are growing vigorously before any irrigation is necessary. When it becomes necessary to irrigate to bring up the crops, poor returns are expected.

The curves shown in figures 10, 11, 12, and 13 show for the four principal crops the relation between the depth of water applied and the yield obtained. The yield per acre for each field shown in Tables 17 and 18 was plotted against the corresponding depth of

water applied and the trend of the curves was governed by points determined by taking the arithmetical average of the coordinates

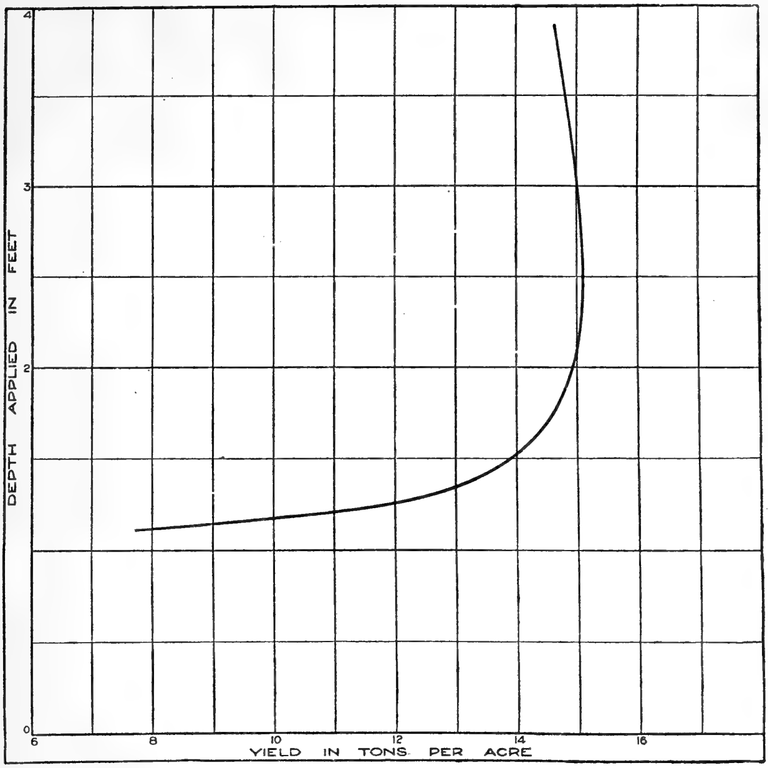


FIG. 12.—Irrigation of sugar beets. Relation between the depth of water applied and the yield.

of points within each half foot of depth. No satisfactory way was found to weight the points to take care of the difference in the area of the fields from which the unit value was determined, and for this reason the curves should be considered only as very close approximations of averages for the valley.

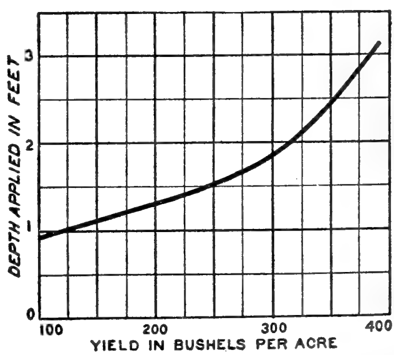


FIG. 13.—Irrigation of potatoes, Relation between the depth of water applied and the yield.

In Tables 9, 17 to 18, and 29 are given all the detailed records of farm irrigation for the two years of the investigation, with footings which summarize the data for each crop each year. The averages in the footings are true averages, involving

factors of time and area where necessary, and will be found to check by the following formula:

$$\frac{\text{Area} \times \text{number irrigations}}{\text{Acres irrigated per day}} \times \text{average flow} \times 1.98 = \text{depth applied} \times \text{area.}$$

Measurements were made by weirs and Cone-Venturi flumes on the farm supply ditches, and the results, therefore, include the losses on the farm.

TABLE 18.—*Irrigation of alfalfa in 1916.*

	Area of field (acres).	Number of irrigations.	Depth of water applied each irrigation (feet).						Total applied depth (feet).	Flow in second-feet.			Acres irrigated per day.	Ratio of hours attended to hours run.	Yield per acre (tons).
			First.	Second.	Third.	Fourth.	Fifth.	Sixth.		Max.	Min.	Ave.			
R. D. Hughes	5.94	2	0.32	0.42	....	....	....	....	0.74	1.99	1.09	1.61	7.97	0.81	**1.40**
	42.82	2	0.57	0.12	....	....	....	....	0.69	3.51	1.68	2.44	14.04	0.58	**1.40**
Wilson & Campbell	29.28	2	1.15	0.95	....	....	....	....	2.10	3.52	0.60	2.13	4.09	0.75	**3.20**
	28.81	3	0.75	0.61	0.15	....	....	....	1.51	3.25	0.67	1.83	7.29	0.67	**4.10**
John A. Mair	15.00	3	0.92	0.80	0.77	....	....	....	2.49	1.54	0.78	1.07	2.55	0.65	**3.76**
C. A. Bartels	22.94	1	0.62	....	....	....	....	....	0.62	4.18	4.18	4.18	13.41	0.61	**3.07**
	23.90	2	0.69	0.72	....	....	....	....	1.41	4.75	4.18	4.27	11.95	0.67	**2.72**
	8.35	2	1.14	0.52	....	....	....	....	1.66	3.74	2.17	3.04	7.29	0.71	**2.72**
	50.58	2	0.64	0.88	....	....	....	....	1.52	4.90	3.40	4.39	11.51	0.66	**3.04**
	27.54	2	0.96	0.18	....	....	....	....	1.14	3.30	1.82	2.80	9.71	0.68	**2.53**
C. A. Culver	11.58	3	0.84	0.69	0.42	....	....	....	1.95	4.12	1.36	3.38	10.37	3.16	**2.14**
	5.87	2	0.58	0.58	....	....	....	....	1.16	3.38	2.54	2.89	9.70	0.65	**2.23**
	8.78	2	0.57	0.28	....	....	....	....	0.85	4.05	1.73	3.69	17.21	0.98	**1.68**
	8.46	2	0.43	0.35	....	....	....	....	0.78	3.46	3.38	3.41	17.28	0.21	**3.97**
	11.62	3	0.82	0.11	0.49	....	....	....	1.42	4.05	1.36	3.22	13.51	0.43	**3.21**
	8.67	2	1.23	0.82	....	....	....	....	2.05	3.82	0.84	2.82	5.47	0.39	**3.94**
	19.74	3	1.15	0.53	0.04	....	....	....	1.72	3.90	1.67	3.07	10.65	0.34	**1.52**
	33.85	3	0.85	0.57	0.11	....	....	....	1.53	5.00	3.46	3.80	14.78	0.39	**3.56**
	7.46	2	1.00	0.36	....	....	....	....	1.36	4.12	3.46	3.74	10.85	0.58	**3.96**
Shafer-Haines	65.70	3	0.52	0.31	0.24	....	....	....	1.07	2.75	1.30	1.92	10.95	0.62	**1.30**
Farmers' National Bank—Page	11.72	1	1.43	....	....	....	....	....	1.43	2.82	0.82	1.65	2.30	0.49	**2.20**
	11.80	1	1.31	....	....	....	....	....	1.31	2.66	1.52	1.89	2.85	0.70	**2.20**
Carpenter-Lyning	9.18	3	1.51	0.70	0.66	....	....	....	2.87	3.10	0.10	1.62	3.36	0.69	**1.20**
	51.64	2	1.60	0.52	....	....	....	....	2.12	3.40	0.30	1.94	3.62	0.66	**2.70**
Chas. F. Mason	18.58	4	1.55	0.84	1.08	0.02	....	....	3.49	3.82	2.26	3.46	7.84	0.60	**5.90**
Jackson-Alles	28.40	3	6.24	1.17	1.31	....	....	....	8.72	6.00	0.25	2.29	1.57	0.42	**3.60**
C. A. Johnson	7.92	3	0.71	0.52	0.14	....	....	....	1.37	2.27	0.10	0.58	2.10	0.68	**3.20**
	14.31	3	0.71	0.34	0.83	....	....	....	1.88	2.27	0.07	1.28	4.06	0.67	**2.50**
Chas. and Henry Rassmussen	68.38	6	1.16	1.03	0.84	1.21	1.56	0.93	6.73	7.45	1.33	4.71	8.34	0.68	**2.40**
M. W. Dealy	30.60	4	0.86	0.78	0.59	0.95	....	....	3.18	9.20	1.34	5.44	13.56	0.80	**3.82**
Jacob Ruff	10.10	3	1.26	2.50	0.37	....	....	....	4.14	4.34	1.05	1.23	1.77	0.38	**1.90**
H. R. Mitchell	5.22	3	0.59	0.49	0.34	....	....	....	1.42	5.00	1.40	2.80	3.85	0.65	**2.00**
	5.48	3	0.65	0.36	0.32	....	....	....	1.33	5.00	1.40	1.90	8.81	0.74	**2.00**
A. L. Bee	33.00	1	0.54	....	....	....	....	....	0.54	2.30	0.90	1.40	3.70	0.35	**3.70**
	20.10	1	0.56	....	....	....	....	....	0.56	2.95	1.15	1.83	5.22	0.41	**2.45**
Frank Wells	33.00	2	1.28	0.09	....	....	....	....	1.37	5.55	0.38	1.71	4.92	0.65	**3.24**
Frank J. Earle	20.55	4	0.73	1.41	0.59	1.26	....	....	3.99	2.51	2.24	2.36	4.70	0.13	**2.89**
	16.30	4	1.54	0.30	1.24	0.40	....	....	3.48	2.53	2.24	2.40	5.40	0.18	**2.07**
C. A. Duncan	22.00	4	0.69	1.61	0.46	0.06	....	....	2.82	6.50	0.70	2.68	7.54	0.71	**3.18**
John Stroh	18.52	3	0.48	0.46	0.30	....	....	....	1.24	5.19	0.78	1.88	9.00	0.81	**2.11**
	12.02	4	0.48	0.41	0.19	0.60	....	....	1.68	3.95	0.16	1.32	6.27	0.74	**2.12**
Michie Bros	42.08	4	0.74	0.88	0.63	0.29	....	....	2.54	4.40	0.97	2.86	8.92	0.84	**2.21**
	8.25	2	1.22	0.38	....	....	....	....	1.60	3.46	2.08	2.42	6.00	0.65	**2.15**
	26.68	3	0.50	0.34	0.66	....	....	....	1.50	4.38	0.30	2.68	10.73	0.70	**3.26**
Total	988.08	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Average	22.45	2.77	1.00	0.65	0.55	0.73	1.56	0.93	2.23	....	....	2.53	6.26	0.57	**2.68**
Maximum	......	6	....	....	....	....	....	....	8.72	9.20	....	5.44	17.28	0.98	**5.90**
Minimum	......	1	....	....	....	....	....	....	0.54	....	0.07	0.58	1.57	0.13	**1.20**

TABLE 19.—*Irrigation of alfalfa in 1917.*

Farm.	Area of field (acres).	Number of irrigations.	Depth of water applied each irrigation (feet).							Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio hours attended to hours run.	Yield per acre (tons).
			First.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.		Maximum.	Minimum.	Average.			
R. D. Hughes	43.00	2	0.60	0.40	....	....	....	....	....	1.00	3.55	2.30	2.69	10.61	1.00	2.50
Wilson-Campbell	27.90	3	.85	1.13	0.10	....	....	....	....	2.08	3.20	1.40	2.40	6.98	.66	3.63
	29.50	2	.96	1.08	....	....	....	....	....	2.04	4.40	2.40	3.40	6.51	.69	3.85
John A. Mair	17.18	5	.15	.24	.70	0.08	0.29	....	....	1.46	1.68	.50	1.09	7.42	.36	4.04
Shafer-Uhrick	43.50	3	.66	.79	.75	....	....	....	....	2.10	4.30	1.95	3.44	9.73	6.42	1.80
Farmers' National Bank-Page	11.90	3	.97	1.20	.08	....	....	....	....	2.25	3.85	.95	2.74	6.03	.62	3.80
	5.21	2	.85	.75	....	....	....	....	....	1.60	2.25	.88	1.88	4.72	.66	2.80
Carpenter-Lyning	9.20	3	2.00	1.63	.02	....	....	....	....	3.65	2.67	.25	1.67	2.06	.68	2.07
	48.30	5	1.32	1.96	.05	.22	.02	....	....	3.57	5.53	.20	1.73	4.82	.60	2.70
Chas. F. Mason	18.00	4	1.08	1.16	.82	1.05	....	....	....	4.11	3.56	1.13	2.73	5.30	.67	5.60
Jackson-Alles	25.00	7	4.58	.38	2.15	2.92	.42	2.62	0.52	13.59	6.16	.67	3.43	3.50	.58	2.40
	22.30	3	3.18	2.10	1.81	....	....	....	....	7.09	5.21	1.22	3.53	2.97	.66	2.40
C. A. Johnson	14.52	2	1.49	.91	....	....	....	....	....	2.40	2.80	.57	1.58	2.61	.56	3.35
	5.11	2	2.60	.90	....	....	....	....	....	3.50	5.12	.00	1.38	1.55	.44	2.84
C. & H. Rassmussen	64.60	5	1.04	.89	1.03	.92	1.06	....	....	4.94	6.70	2.80	4.70	9.65	.58	2.40
M. W. Dealy	30.60	4	1.06	.88	.84	.64	....	....	....	3.42	11.32	.63	7.78	19.52	.85	4.40
Jacob Ruff	10.10	2	2.13	1.68	....	....	....	....	....	3.82	2.94	1.50	1.95	2.03	.50	2.97
A. L. Bee	40.00	2	.63	.50	....	....	....	....	....	1.13	3.46	.77	1.82	6.34	.65	3.35
	15.00	3	1.03	.55	.49	....	....	....	....	2.07	3.41	.25	1.89	5.44	.69	2.10
Frank Wells	32.18	3	.92	1.56	1.76	....	....	....	....	4.24	4.18	.14	1.55	2.18	.47	3.78
Frank J. Earle	20.55	3	.30	.36	.38	....	....	....	....	1.04	3.30	1.27	1.65	9.42	.19	3.49
	16.22	3	.45	.67	.14	....	....	....	....	1.26	1.90	1.24	1.53	7.25	.04	2.26
C. A. Duncan	11.03	5	1.11	.96	.33	.24	.17	....	....	2.81	2.98	.45	1.83	6.43	.34	1.92
John Stroh	12.02	2	.39	.52	....	....	....	....	....	.91	4.06	.57	2.61	11.31	.39	1.87
	17.05	4	.14	.34	.11	.22	....	....	....	.81	3.28	.73	1.93	19.03	.46	0.96
Michie Bros	36.26	3	.86	.83	1.04	....	....	....	....	2.73	6.62	1.51	3.82	8.31	.60	2.60
	32.58	3	.42	.74	.42	....	....	....	....	1.58	6.62	.37	3.60	13.46	.62	2.84
	8.25	3	.49	1.01	.92	....	....	....	....	2.42	5.10	1.51	4.02	9.86	.55	2.85
Fred Wells	1.61	1	.87	....	....	....	....	....	....	.87	.90	.72	.75	1.64	.55	5.15
Wilson Bros	16.80	1	.52	....	....	....	....	....	....	.52	2.40	1.88	2.29	8.76	.91	2.10
Total	685.57	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Average	22.85	3.37	1.07	.94	0.76	.82	.52	2.62	.52	3.07	....	....	2.65	5.78	.57	2.84
Maximum	....	7	....	....	....	....	....	....	....	13.59	11.32	....	7.78	19.52	1.00	5.60
Minimum	....	1	....	....	....	....	....	....	....	.52	....	.00	.75	1.55	.40	.96

TABLE 20.—*Irrigation of wheat in 1916 and 1917.*

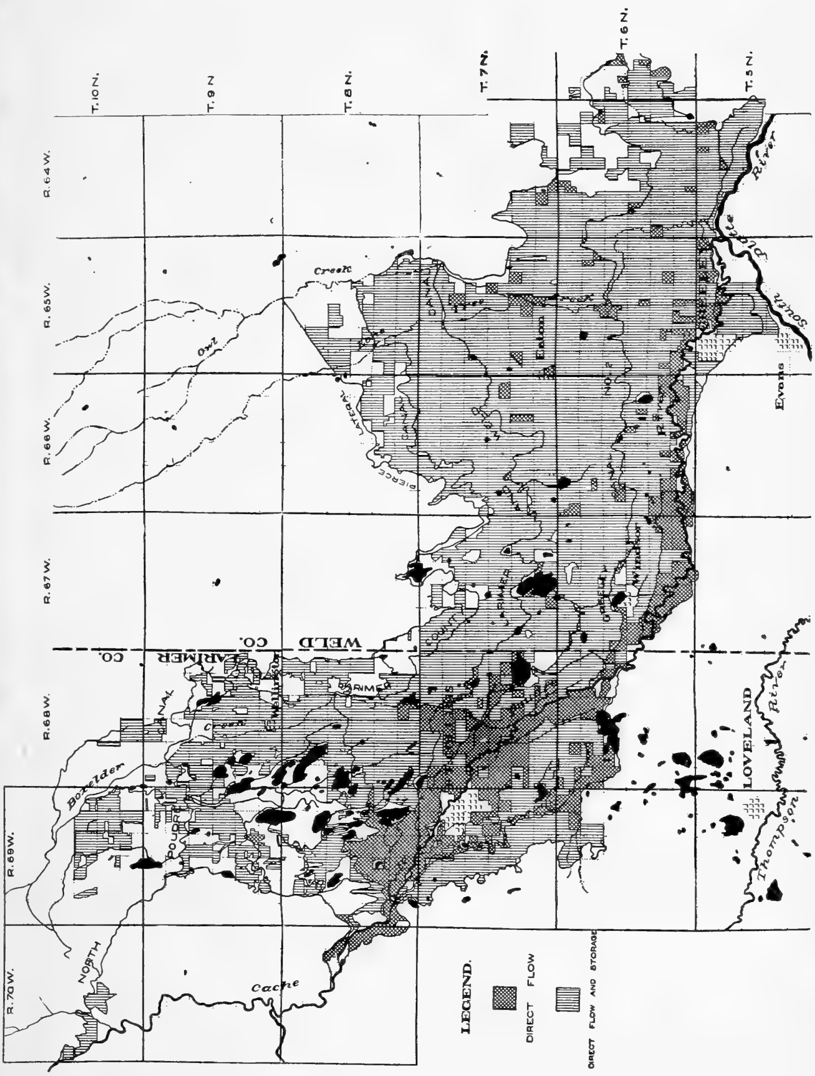
Field.	Area of field (acres).	Number of irrigations.	Depth for each irrigation (feet).		Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (bushels).
			First.	Second.		Maximum.	Minimum.	Average.			
1916.											
C. A. Bartels	40.79	1	0.80	......	0.80	5.10	3.38	4.59	11.39	0.84	43.50
C. A. Culver	29.88	1	1.79	......	1.79	3.63	1.58	3.16	3.49	.48	13.70
Farmers' National Bank-Page	7.68	2	1.02	1.30	2.32	2.02	1.38	1.75	2.99	.52	26.20
	8.22	2	.74	.81	1.55	2.32	1.55	1.80	4.61	.58	23.80
Carpenter-Lyning	13.00	2	1.22	.87	2.09	2.96	1.02	1.16	2.27	.74	9.40
C. A. Johnson	15.12	2	.64	.31	.95	2.44	.14	1.32	5.54	.69	13.70
M. W. Dealy	58.60	1	.60	......	.60	4.63	2.60	3.25	10.82	.81	26.40
H. R. Mitchell	42.00	1	.44	......	.44	4.75	2.16	3.75	17.10	.85	27.00
A. L. Bee	20.30	1	.72	......	.72	2.40	.90	1.42	3.04	.43	27.20
	10.55	1	.77	......	.77	2.05	.90	1.38	2.58	.39	33.20
Frank Wells	3.00	1	.60	......	.60	1.44	1.30	1.40	4.50	.62	33.30
Frank J. Earle	9.59	1	.74	......	.74	2.53	2.53	2.53	6.77	.22	33.40
	14.05	2	.48	.41	.89	2.91	2.53	2.69	12.05	.34	31.00

TABLE 20.—*Irrigation of wheat in 1916 and 1917*—Continued.

Field.	Area of field (acres).	Number of irrigations.	Depth for each irrigation (feet).		Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (bushels).
			First.	Second.		Maximum.	Minimum.	Average.			
1916.											
C. A. Duncan	20.39	2	2.18	.63	2.81	6.50	.30	2.27	3.20	.30	33.00
Michie Brothers	15.36	1	.17		.17	3.03	.62	1.54	17.54	.71	51.30
	7.39	1	1.30		1.30	4.32	.08	1.96	3.00	.54	50.30
Total	315.92										
Average	19.74	1.27	.87	.65	1.03			2.13	5.20	.55	25.39
Maximum		2			2.81	4.75		4.59	17.54	.85	51.30
Minimum		1			.17		.08	1.16	2.27	.22	9.40
1917.											
Shafer-Uhrick	11.93	1	1.00		1.00	2.16	2.16	2.16	4.28	.31	34.00
C. A. Johnson	15.90	2	.33	.56	.89	3.40	.40	1.60	10.74	.40	?
M. W. Dealy	58.60	1	.82		.82	7.34	1.75	3.71	8.99	.88	22.00
A. L. Bee	30.00	1	.98		.98	2.42	1.09	1.79	3.62	.63	33.30
Frank Wells	5.00	1	1.07		1.07	3.92	.18	1.21	2.22	.57	40.00
FrankJ. Earle	11.61	1	1.03		1.03	3.60	1.65	2.72	5.26	.57	43.60
	9.56	1	.84		.84	1.76	1.08	1.39	3.28	.50	29.30
	4.60	1	1.63		1.63	2.16	1.89	2.06	2.51	.45	37.00
C. A. Duncan	12.45	1	2.71		2.71	3.53	1.95	3.18	2.32	.54	42.40
Michie Brothers	15.36	1	.83		.83	5.10	3.78	4.01	9.57	.75	46.70
Total	175.01										
Average	17.50	1.09	.99	.56	1.04			2.41	4.99	.59	32.03
Maximum		2			2.71	7.34		4.01	10.74	.88	46.70
Minimum		1			.82		.18	1.21	2.22	.31	22.00

TABLE 21.—*Irrigation of oats in 1916 and 1917.*

Farm.	Area of field (acres).	Number of irrigations.	Depth applied each irrigation (feet).				Total depth applied, feet.	Flow in second-feet.			Acres irrigation per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (bushels).
			First.	Second.	Third.	Fourth.		Maximum.	Minimum.	Average.			
1916.													
Wilson-Campbell	17.10	2	1.21	0.13.			1.33	3.25	1.22	2.50	7.43	0.64	70.00
C. A. Bartels	9.51	1	.80				.80	4.19	4.19	4.19	10.37	.64	20.80
C. A. Culver	10.56	1	1.41				1.41	5.00	1.58	2.83	3.98	.81	72.90
Charles F. Mason	16.10	4	.45	.81	0.88	0.92	3.07	3.94	3.00	3.45	8.92	.86	65.20
A. L. Bee	12.50	1	1.39				1.39	2.95	0.55	1.73	1.61	.39	53.30
Frank Wells	6.76	1	.60				.60	1.44	1.30	1.40	4.63	.60	42.90
Total	81.24												
Average	11.61	1.81	.98	.46	.88	.92	1.51			2.35	5.55	.64	52.50
Maximum		4					3.07	5.00		4.19	10.36	.86	72.90
Minimum		1					.60		.55	1.40	1.61	.39	20.80
1917.													
Wilson-Campbell	10.10	2	1.15	.86			2.01	4.70	1.50	2.80	5.61	.88	61.00
Shafer-Uhrick	33.30	1	.70				.70	3.19	1.00	2.04	5.79	.65	23.20
A. L. Bee	12.50	1	.60				.60	2.00	1.39	1.90	6.25	.67	28.00
Farmers' National Bank-Page	14.60	2	.60	.50			1.10	3.90	.95	2.00	7.22	.59	29.70
Charles F. Mason	8.90	2	1.26	1.18			2.44	3.56	1.10	2.99	5.27	.47	77.80
Frank Wells	8.54	1	1.07				1.07	3.29	.18	1.21	2.23	.58	76.50
C. A. Duncan	11.60	2	1.28	1.09			2.37	2.70	1.60	2.02	3.37	.33	62.60
Michie Brothers	5.20	2	1.19	.48			1.67	6.34	3.10	5.20	12.02	.82	70.40
Minor-Miller	9.61	2	.45	.21			.66	2.40	.52	1.30	7.90	1.00	56.70
Total	114.34												
Average	12.71	1.52	.85	.73			1.23			2.16	5.32	.61	44.90
Maximum		2					2.44	6.34		5.20	12.02	1.00	77.80
Minimum		1					.60		.18	1.21	2.23	.33	23.20



COMPARISON OF THE AREA IRRIGATED BY DIRECT FLOW AND THE AREA IRRIGATED BY DIRECT FLOW AND STORED WATER.

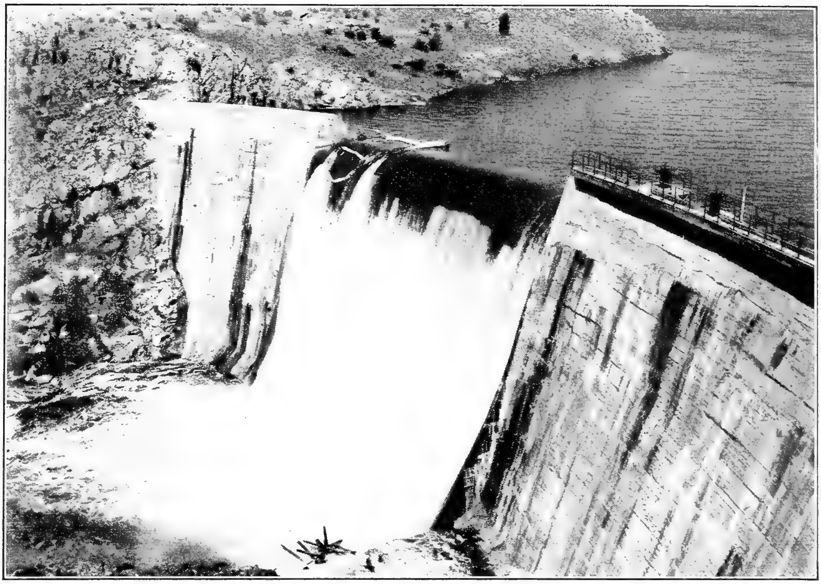


FIG. 1.—HALLIGAN DAM OF THE NORTH POUDRE SYSTEM. DEPTH OF 1½ FEET ON THE SPILLWAY.

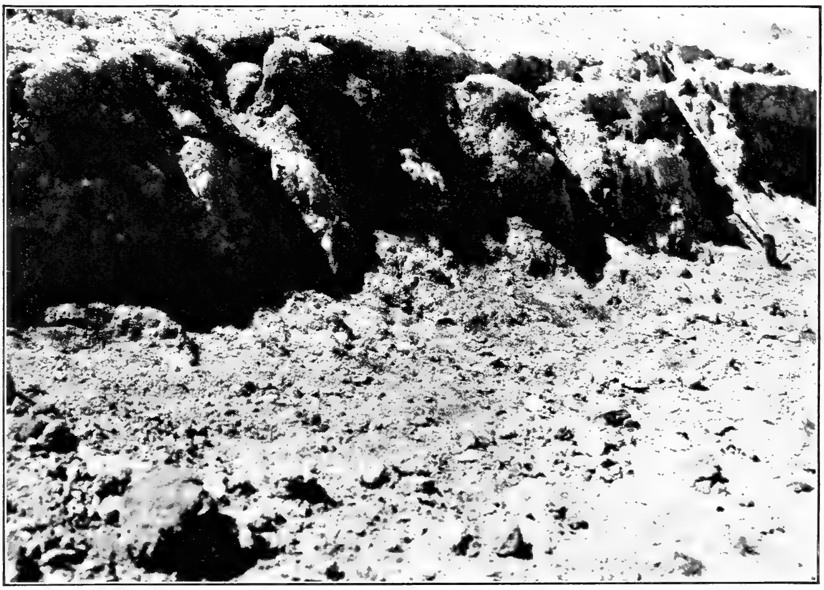


FIG. 2.—EFFECT OF WAVE ACTION ON THE INNER SLOPE OF THE DAM OF NORTH POUDRE RESERVOIR NO. 15.

TABLE 22.—*Irrigation of barley in 1916 and 1917.*

Farm.	Area of field (acres).	Number of irrigations.	Depth each irrigation (feet).			Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (bushels).
			First.	Second.	Third.		Maximum.	Minimum.	Average.			
1916.												
R. D. Hughes	35.20	1	0.36	......	......	0.36	2.92	1.81	2.41	13.25	0.89	39.80
John A. Mair	17.46	1	1.18	......	......	1.18	2.09	1.26	1.86	3.13	.89	38.10
C. A. Culver	10.73	1	.70	......	......	.70	2.95	2.95	2.95	8.32	.68	36.80
Shafer-Haines	13.85	1	.54	......	......	.54	2.75	2.75	2.75	10.07	.73	6.40
Farmers' National Bank-Page.	14.63	2	.96	1.28	......	2.24	2.32	1.38	1.92	3.39	.57	18.50
Carpenter-Lyning	16.60	2	1.50	.83	......	2.33	3.56	1.02	1.50	2.52	.71	14.30
Jackson-Alles	9.40	2	1.68	2.28	......	3.96	3.60	2.65	3.39	3.39	.65	54.50
C. A. Johnson	7.43	1	1.82	......	......	1.82	3.80	.87	2.20	2.92	.74	17.20
A. L. Bee	19.40	1	.14	......	......	.14	3.25	2.25	2.30	31.04	.27	13.30
Frank Wells	10.34	1	1.04	......	......	1.04	1.64	1.30	1.48	2.82	.63	15.00
Frank J. Earle	21.00	1	1.11	......	......	1.11	2.91	2.53	2.62	4.67	.41	59.50
	9.56	1	1.33	......	......	1.33	2.31	2.16	2.20	3.27	.30	33.50
	3.14	1	1.30	......	......	1.30	2.91	2.91	2.91	4.43	.71	47.80
Michie Brothers	9.36	1	1.43	......	......	1.43	3.43	2.95	3.24	4.49	.74	41.45
Minor-Wilson	25.50	1	.78	......	......	.78	2.13	1.85	2.02	5.14	.70	66.00
Total	224.45	......	......	......	......	......	......	......	......	......	......	......
Average	14.02	1.18	.91	1.33	......	1.15	......	......	2.16	4.39	.66	35.47
Maximum	......	2	......	......	......	3.96	3.80	......	3.39	31.04	.89	66.00
Minimum	......	1	......	......	......	.14	......	.87	1.48	2.52	.27	6.40
1917.												
John A. Mair	9.28	1	.68	......	......	.68	1.44	1.35	1.42	4.12	.93	62.20
Shafer-Uhrick	5.43	1	1.00	......	......	1.00	.99	.99	.99	1.95	.31	5.50
Carpenter-Lyning	5.83	1	.97	......	......	.97	1.60	1.60	1.60	5.83	.50	40.00
C. A. Johnson	12.64	1	1.25	......	......	1.25	4.00	1.10	2.33	3.70	.16	......
Farmers' National Bank-Page.	7.81	2	2.10	1.01	......	3.11	3.40	.73	1.96	2.50	.51	39.70
	3.03	2	.86	.77	......	1.65	1.35	.53	1.13	2.74	.66	33.30
	7.68	2	1.40	.80	......	2.20	4.10	1.07	3.12	5.50	.75	18.20
A. L. Bee	5.00	1	1.98	......	......	1.98	1.90	1.09	1.40	1.39	.37	46.00
Frank Wells	15.30	1	.85	......	......	.85	2.47	.72	1.73	4.04	.75	63.00
Frank J. Earle	21.00	1	1.15	......	......	1.15	3.30	1.44	2.27	3.91	.39	60.00
	9.49	2	.54	.46	......	1.00	1.92	1.22	1.35	5.33	.53	56.90
Michie Brothers	7.39	1	.87	......	......	.87	4.02	3.78	3.97	9.10	.41	46.30
	9.36	1	1.08	......	......	1.08	4.02	3.48	3.94	7.24	.64	46.40
	5.90	2	.17	1.25	......	1.42	5.53	3.94	5.22	14.52	.87	46.40
Minor-Miller	4.51	2	.47	.29	......	.76	1.36	.75	1.14	6.00	1.00	61.40
Wilson-Bass	10.40	3	.19	.19	.62	1.00	2.07	1.94	2.06	11.99	.81	52.80
Total	140.05	......	......	......	......	......	......	......	......	......	......	......
Average	8.75	1.42	.98	.64	.62	1.25	......	......	2.00	4.52	.55	49.16
Maximum	......	3	......	......	......	3.11	5.53	......	5.22	14.52	1.00	63.00
Minimum	......	1	......	......	......	.68	......	.53	.99	1.39	.16	5.50

TABLE 23.—*Irrigation of sugar beets in 1916.*

Farm.	Area of field (acres).	No. of irrigations.	Water applied each irrigation (feet).					Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (tons).
			First.	Second.	Third.	Fourth.	Fifth.		Maximum.	Minimum.	Average.			
R. D. Hughes	13.50	3	0.90	0.60	0.17	....	....	1.64	2.80	1.34	2.12	7.57	0.89	12.40
Wilson-Campbell	17.10	3	.39	.30	.61	....	....	1.30	4.05	.75	2.65	12.13	1.00	10.30
John A. Mair	32.54	3	.67	.55	.08	....	....	1.30	1.59	.54	1.01	4.65	.77	10.97
	7.65	3	.90	.86	1.12	....	....	2.88	1.44	.68	1.20	2.47	.76	10.85
C. A. Bartels	24.68	3	1.46	.87	1.49	....	....	3.82	4.97	4.10	4.47	6.97	.68	17.11
	33.60	3	.78	1.17	.78	....	....	2.73	5.15	1.00	4.09	8.90	.89	15.81

TABLE 23.—*Irrigation of sugar beets in 1916*—Continued.

Farm.	Area of field (acres).	No. of irrigations.	Water applied each irrigation (feet).					Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (tons).
			First.	Second.	Third.	Fourth.	Fifth.		Maximum.	Minimum.	Average.			
C. A. Culver	31.74	2	1.07	.98	....	....	....	2.05	4.05	1.32	3.77	7.14	.71	9.85
	36.29	2	.79	.64	....	....	....	1.43	4.75	3.28	4.21	11.69	.82	9.85
	2.30	2	.53	.90	....	....	....	1.43	3.68	2.65	2.95	4.08	1.00	9.85
	6.12	2	.58	.52	....	....	....	1.10	3.97	2.65	3.60	6.53	.67	9.85
	2.06	1	.32	....	....	....	....	.32	3.97	3.97	3.97	24.72	1.00	9.85
Shafer-Haines	20.80	4	.46	.84	.33	.45	....	2.07	2.45	1.07	1.12	5.20	.60	8.40
Carpenter-Lyning	21.10	2	.57	.66	....	....	....	1.23	4.75	.08	.86	2.80	.69	7.50
	11.90	3	.78	.56	.82	....	....	2.16	4.75	.08	.66	1.84	.66	7.50
Charles F. Mason	9.00	4	.45	.73	1.14	.49	....	2.81	5.89	1.63	3.48	9.76	.64	15.00
	17.20	4	.24	.41	.48	.75	....	1.88	5.62	1.57	3.48	14.74	.66	15.90
Jackson-Alles	9.26	4	.80	2.06	.49	1.62	....	4.96	5.50	1.85	3.04	4.85	.56	13.80
C. A. Johnson	12.92	3	.26	.29	.16	....	....	.71	1.06	.13	.52	4.27	.69	9.00
Charles and Henry Rassmussen	29.60	4	.51	.57	.22	.28	....	1.58	4.10	1.42	2.30	11.66	.89	15.70
	9.90	3	.83	.49	.83	....	....	2.15	3.49	1.50	1.90	5.14	.84	11.10
	11.80	2	1.29	.44	....	....	....	1.73	1.85	.90	1.33	3.05	.79	6.20
H. R. Mitchell	47.50	2	.57	.26	....	....	....	.83	5.50	1.40	3.10	7.89	.69	13.70
A. L. Bee	19.60	2	.60	.48	....	....	....	1.08	2.50	.70	.98	3.57	.75	14.78
Frank Wells	13.54	2	.27	.37	....	....	....	.64	2.59	.40	1.13	6.99	.84	12.67
Frank J. Earle	11.61	3	1.00	.96	.61	....	....	2.57	2.38	2.24	2.31	5.36	.55	13.20
	11.24	3	.71	.57	.41	....	....	1.69	2.45	2.24	2.34	8.26	.85	13.00
	4.02	3	.55	.00	.57	....	....	1.72	2.45	2.24	2.33	8.04	.78	10.70
C. A. Duncan	22.40	2	2.38	1.30	....	....	....	3.68	6.40	.20	1.63	1.75	.65	9.94
John Stroh	5.88	3	1.51	1.25	1.90	....	....	4.66	7.37	1.00	4.42	5.64	.55	11.24
	5.41	2	.71	2.88	....	....	....	3.59	6.22	.26	3.55	3.93	.61	11.24
	34.74	3	.94	1.25	1.21	....	....	3.40	6.22	.36	3.58	6.25	.70	11.24
Michie Brothers	6.69	5	.39	.64	.50	.54	.80	2.87	3.36	1.96	2.73	9.45	.88	17.10
	5.88	3	.17	.42	.69	....	....	1.28	2.45	1.96	2.32	10.86	.69	17.10
Minor-Wilson	10.40	3	.80	.59	.81	....	....	2.20	2.33	1.88	2.06	5.55	.96	13.00
	14.10	1	.70	....	....	....	....	.70	2.26	1.94	2.09	5.94	.80	13.90
	7.30	3	.62	.56	.73	....	....	1.91	2.96	1.57	2.07	6.42	.99	13.80
Total	584.32	....	....	....	....	....	....	....	....	....	....	....	....	.....
Average	15.79	2.74	.78	.74	.67	.58	.80	1.86	....	....	1.91	5.58	.73	12.15
Maximum	......	5	....	....	....	....	....	4.96	7.37	....	4.47	24.72	1.00	17.10
Minimum	......	1	....	....	....	....	....	.32	....	.08	.52	1.75	.55	6.20

TABLE 24.—*Irrigation of sugar beets in 1917.*

Farm.	Area of field (acres).	Number of irrigations.	Depth of water applied each irrigation (feet).					Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (tons).
			First.	Second.	Third.	Fourth.	Fifth.		Maximum.	Minimum.	Average.			
R. D. Hughes	16.20	2	0.98	0.43	....	....	....	1.41	2.70	1.50	1.97	5.40	0.99	11.05
Wilson-Campbell	21.50	3	.59	.76	1.05	....	....	2.40	4.20	2.00	2.90	7.51	.64	18.92
John Mair	31.38	2	.21	.81	....	....	....	1.02	1.40	.04	.87	3.36	.57	11.73
	13.12	4	.37	.28	.07	.45	....	1.17	1.40	.35	.84	5.75	.78	11.73
Shafer-Uhrick	10.37	3	.59	.14	.36	....	....	1.09	1.90	1.54	1.64	9.00	.60	4.82
Carpenter-Lyning	12.60	4	1.50	.99	.78	1.76	....	5.03	5.18	.31	1.68	2.50	.65	14.80
Chas. F. Mason	15.75	5	.30	.21	.18	.19	.45	1.33	3.25	1.88	2.69	20.11	.89	17.20
Jackson-Alles	22.50	4	1.00	.15	.64	.30	....	2.09	5.15	1.65	4.29	16.18	.64	14.80
	10.30	5	.53	1.37	1.77	1.56	1.31	6.59	4.06	.74	2.62	3.92	.61	15.00
Chas. and Henry Rassmussen	29.60	5	.02	.43	.31	.35	.40	1.51	3.00	.50	1.68	11.01	.71	15.83
	11.80	3	.14	.82	.11	....	....	1.07	2.20	.20	.76	4.23	.76	15.83
C. A. Johnson	7.91	2	.28	.46	....	....	....	.74	2.15	.50	.89	4.72	.74	8.15
A. L. Bee	20.00	2	.59	.84	....	....	....	1.43	3.04	.77	1.45	4.03	.67	14.20
Frank J. Earle	9.48	2	.94	.41	....	....	....	1.35	1.82	1.19	1.31	3.86	.85	12.34
	4.02	3	.56	.32	.27	....	....	1.15	2.55	1.19	1.68	7.52	.91	8.95
	9.59	3	.28	.74	.24	....	....	1.26	2.72	1.28	1.86	9.10	.89	10.00
C. A. Duncan	30.86	3	.69	.77	.61	....	....	2.07	3.20	.70	1.81	5.17	.46	12.62
John Stroh	3.71	2	.57	.81	....	....	....	1.38	4.14	1.54	3.01	8.69	1.00	10.85
	40.15	3	.41	1.21	.16	....	....	1.78	4.05	.20	1.95	6.55	.82	10.85

TABLE 24.—*Irrigation of sugar beets in 1917*—Continued.

Farm.	Area of field (acres).	Number of irrigations.	Depth of water applied each irrigation (feet).					Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (tons).
			First.	Second.	Third.	Fourth.	Fifth.		Maximum.	Minimum.	Average.			
Michie Brothers	6.69	3	.73	.76	.61	....	....	2.10	4.26	2.13	3.36	9.49	.97	12.41
	5.88	4	.95	.51	.54	.60	....	2.60	5.89	3.25	4.25	12.94	.92	14.59
Fred Wells	12.25	2	.55	.38	....	....	....	.93	1.10	.15	.68	2.89	.62	15.42
Minor-Miller	14.70	3	.48	.83	.57	....	....	1.88	2.53	1.81	2.08	6.78	.56	14.80
Wilson-Bass	6.52	2	.34	.46	....	....	....	.80	2.40	1.40	1.61	8.02	.51	9.96
	8.81	3	1.50	1.29	.90	....	....	3.69	2.40	1.02	1.55	2.49	.58	9.96
Total	375.69	....	....	....	....	....	....	....	....	....	....	....	....	....
Average	15.03	3.15	.55	.95	.47	.62	.58	1.87	....	....	1.75	5.87	.68	13.21
Maximum	......	5	....	....	....	....	....	6.59	5.89	....	4.29	20.11	1.00	18.92
Minimum	......	2	....	....	....	....	....	.74	....	.04	.68	2.49	.46	4.82

TABLE 25.—*Irrigation of potatoes in 1916.*

Farm.	Area of field (acres).	Number of irrigations.	Depth of water applied each irrigation (feet).						Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24 hour day.	Ratio hours attended to hours run.	Yield per acre (bushels).
			First.	Second.	Third.	Fourth.	Fifth.	Sixth.		Maximum.	Minimum.	Average.			
R. D. Hughes	16.20	3	0.50	0.42	0.41	....	....	....	1.43	2.82	1.31	1.84	8.22	0.78	270.00
	11.60	2	.36	.40	....	....	....	....	.74	2.80	2.74	2.76	4.46	.86	344.00
Wilson-Campbell	5.75	4	.42	.26	.14	0.63	....	....	1.45	2.70	1.18	1.88	10.32	.68	204.00
	34.50	5	.20	.41	.17	.71	0.52	....	2.02	4.22	.68	2.72	13.38	.58	264.00
	4.72	3	.48	.15	.88	....	....	....	1.51	2.96	1.18	1.72	6.80	.60	48.00
Shafer-Haines	9.48	4	.31	.32	.30	.48	....	....	1.41	1.35	.45	1.11	6.21	.66	222.40
Farmers' National Bank-Page	19.60	5	.14	.16	.36	.72	.89	....	2.27	3.75	1.60	2.09	9.17	.65	264.00
	11.60	5	.33	.40	.33	.44	.60	....	2.10	1.84	1.58	1.73	8.07	.78	230.00
Carpenter-McMurray	4.42	3	.37	.90	.58	....	....	....	1.85	4.18	.99	1.85	5.95	.93	181.00
Carpenter-Lyning	7.95	2	.70	.54	....	....	....	....	1.24	4.75	.40	.55	1.75	.67	196.00
Charles F. Mason	17.20	6	.47	.27	.30	.31	.40	0.30	2.05	4.02	2.81	3.65	20.90	.97	250.00
Minor-Wilson	6.23	2	.61	.54	....	....	....	....	1.15	2.00	1.94	1.94	6.65	.94	147.00
	8.04	2	.63	.57	....	....	....	....	1.20	2.13	1.75	1.93	6.33	.70	216.00
Total	157.29	....	....	....	....	....	....	....	....	....	....	....	....	....	......
Average	12.10	4.05	.38	.38	.32	.53	.58	.30	1.71	....	....	1.95	9.17	.71	242.68
Maximum	......	6	....	....	....	....	....	....	2.27	4.75	....	3.65	20.90	.97	344.00
Minimum	......	2	....	....	....	....	....	....	.74	....	.40	.55	1.75	.58	48.00

TABLE 26.—*Irrigation of potatoes in 1917.*

Farm.	Area of field (acres).	Number of irrigations.	Water applied each irrigation (feet).						Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio hours attended to hours run.	Yield per acre (bushels).
			First.	Second.	Third.	Fourth.	Fifth.	Sixth.		Maximum.	Minimum.	Average.			
R. D. Hughes	25.10	3	0.41	0.52	0.11	....	....	....	1.04	2.90	1.80	2.68	15.31	0.99	271.00
	15.20	4	.66	.39	.36	0 38	....	....	1.79	2.90	1.55	2.18	10.36	.75	309.20
Wilson-Campbell	11.81	4	.24	.32	.33	.42	....	....	1.31	2.70	1.00	2.00	12.12	.50	235.00
	43.45	3	.77	.45	.47	....	....	....	1.69	5.00	.70	2.04	7.24	.54	235.00
Shafer-Uhrick	22.40	3	.69	.63	.42	....	....	....	1.74	3.56	.15	2.00	7.00	.68	153.00
	3.69	3	.59	.14	.35	....	....	....	1.08	.68	.55	.58	3.20	.60	154.00
Farmers' National Bank-Page	11.80	5	.33	.31	.51	.62	0.56	....	2.33	2.00	.50	1.04	4.60	.72	204.00

TABLE 26.—*Irrigation of potatoes in 1917*—Continued.

Farm.	Area of field (acres).	Number of irrigations.	Water applied each irrigation (feet).						Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio hours attended to hours run.	Yield per acre (bushels).
			First.	Second.	Third.	Fourth.	Fifth.	Sixth.		Maximum.	Minimum.	Average.			
Carpenter-McMurray	11.70	3	.84	.32	.34	....	....	....	1.50	2.08	.45	1.66	6.58	.87	171.00
Carpenter-Lyning	12.69	2	.36	.77	....	....	....	....	1.13	1.94	.82	1.61	5.67	.68	284.00
	3.60	3	.97	.92	1.39	....	....	....	3.28	4.10	1.81	2.39	4.36	.62	8.30
	7.95	3	.45	1.11	.36	....	....	....	1.92	3.13	1.17	1.76	5.46	.83	352.00
	3.90	5	.21	.23	.08	.10	.23	....	.85	2.13	.41	.91	10.40	.77	204.00
Charles F. Mason	9.00	5	.61	.10	.17	.12	.30	....	1.30	3.56	2.07	2.92	22.27	.67	278.00
	17.00	6	.28	.09	.19	.43	.37	1.08	2.45	3.40	.50	2.57	11.33	.65	300.00
	6.35	5	.16	.20	.22	.52	1.10	....	2.20	3.56	2.60	2.98	13.37	.69	300.00
Jackson-Alles	8.25	5	.52	.86	1.97	4.10	2.16	....	9.61	4.47	1.50	2.97	3.07	.62	29.00
	8.85	6	5.88	1.01	1.22	1.31	4.88	2.64	16.94	4.72	.03	2.15	1.51	.62	226.00
Charles and Henry Rassmussen	9.90	5	.72	.67	.47	.36	.58	....	2.79	2.80	1.10	2.30	7.92	.75	374.00
	4.10	5	.98	.64	.76	.81	.71	....	3.90	4.90	3.20	3.70	9.42	.85	320.00
Frank Wells	13.21	3	.69	.98	.74	....	....	....	2.41	2.31	.27	1.03	2.54	.40	302.00
	9.76	2	.75	.38	....	....	....	....	1.13	2.44	.56	1.15	4.00	.50	250.00
John Stroh	1.42	2	.56	.63	....	....	....	....	1.19	3.78	2.02	2.74	9.09	.67	246.00
Minor-Miller	1.47	3	.34	.48	.61	....	....	....	1.43	2.14	1.26	1.82	7.56	.86	274.00
	18.80	3	.61	.89	.59	....	....	....	2.05	2.46	1.94	2.15	6.32	.99	340.00
Wilson-Bass	3.12	2	.48	.26	....	....	....	....	.74	2.70	1.12	1.79	9.66	1.00	93.00
Total	284.52	....	....	....	....	....	....	....	....	....	....	....	....	....	......
Average	11.38	3.65	.74	.53	.48	.55	.76	.62	2.47	....	....	2.00	5.85	.67	223.11
Maximum	......	6	....	....	....	....	....	....	16.94	5.00	....	3.70	22.27	1.00	374.00
Minimum	......	2	....	....	....	....	....	....	.74	....	.03	.58	1.51	.40	8.30

TABLE 27.—*Irrigation of beans in 1916 and 1917.*

Farm.	Area of field (acres).	Number of irrigations.	Depth applied each irrigation (feet).					Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio hours attended to hours run.	Yield per acre (bushels).
			First.	Second.	Third.	Fourth.	Fifth.		Maximum.	Minimum.	Average.			
1916.														
Wilson-Campbell	11.70	3	0.20	0.37	0.28	....	....	0.85	1.73	0.50	1.36	9.57	0.68	23.80
Shafer-Haines	33.30	2	.36	.08	....	....	....	.44	1.83	1.11	1.46	13.27	.64	15.80
Carpenter-McMurray	7.28	2	.44	.28	....	....	....	.72	3.40	.87	1.22	6.72	.83	10.40
Charles F. Mason	8.78	4	.28	.23	.29	.25	....	1.06	3.82	2.46	3.17	23.41	.71	29.30
	8.10	3	.19	.17	.21	....	....	.57	3.82	2.57	3.03	31.52	1.00	24.50
Minor-Wilson	6.65	2	.62	.58	....	....	....	1.20	2.96	1.57	2.28	7.48	1.00	20.00
Total	75.81	....	....	....	....	....	....	....	....	....	....	.....	....	.....
Average	12.64	2.49	.34	.21	.26	.25	....	.68	....	....	1.75	12.68	.75	19.30
Maximum	......	4	....	....	....	....	....	1.20	3.82	....	3.17	31.52	1.00	29.30
Minimum	......	2	....	....	....	....	....	.44	....	.50	1.22	6.72	.64	10.40
1917.														
R. D. Hughes	20.30	2	.30	.22	....	....	....	.52	2.55	1.90	2.17	16.66	.89	13.60
Wilson-Campbell	9.71	2	.40	.61	....	....	....	1.01	2.30	2.00	2.05	7.99	.91	24.40
Shafer-Uhrick	13.04	2	.59	.38	....	....	....	.97	2.50	1.93	2.09	8.69	.65	6.90
Farmers' National Bank-Page	11.60	2	.15	.22	....	....	....	.37	1.30	.95	1.21	12.95	.70	34.20
	11.40	3	.14	.40	.27	....	....	.81	2.00	.90	1.53	11.09	.55	27.70
Carpenter-Lyning	29.60	2	.49	.32	....	....	....	.81	3.56	.87	2.21	10.89	.85	17.20
C. F. Mason	9.51	4	.11	.12	.12	.16	....	.51	3.48	2.60	2.84	45.67	.98	29.00
	17.40	4	.12	.16	.07	.13	....	.48	3.56	2.20	2.70	44.54	.92	33.30
	8.35	5	.11	.12	.22	.14	.37	.96	3.56	2.00	2.56	22.03	1.00	30.20
	8.35	3	.14	.16	.12	....	....	.42	3.56	2.81	3.08	41.32	1.00	30.20
	1.90	3	.12	.11	.11	....	....	.34	3.56	2.81	3.14	54.80	1.00	27.60
	8.36	4	.14	.12	.20	.17	....	.63	3.48	2.26	2.78	34.90	.89	36.20
Total	149.52	....	....	....	....	....	....	....	....	....	....	.....	....	.....
Average	12.46	2.78	.28	.26	.18	.15	.37	.69	....	....	2.19	17.48	.82	24.50
Maximum	......	5	....	....	....	....	....	1.01	3.56	....	3.14	54.80	1.00	36.20
Minimum	......	2	....	....	....	....	....	.34	....	.87	1.21	7.99	.55	6.90

RESERVOIRS.

The settlement of the Cache la Poudre Valley proceeded very rapidly after 1870 and the consequent extension of irrigation soon brought out the necessity for reservoirs. The stream was over-appropriated and as the irrigated area under early canals increased, the later canals suffered more and more from shortage of water. Conditions under the older canals became acute when continuous grain cropping had exhausted the land and the farmers were compelled to turn their attention to more profitable crops such as alfalfa, potatoes, and later, sugar beets. These crops required irrigation later in the season when water was available for only a few small ditches with early priorities. To meet these conditions the construction of reservoirs became general and has continued until nearly all the cultivated land of the valley is supplied to some extent with stored water. This is clearly shown in Plate XV, given to afford a comparison between the total area irrigated in 1916 and the area which received reservoir water that year.

With reference to organization, the reservoirs of the valley may be divided into 3 classes. The largest class is made up of small private reservoirs built by the individual to make the best use of a small head, to free himself from the limitations imposed by rotation periods, or to save a few acre-feet for a late irrigation. The second class includes the reservoirs which are owned as a part of a canal system and store water to be distributed as a part of the general supply. The majority of the reservoirs of this class belong to either the North Poudre Irrigation Co. or the Water Supply & Storage Co. The canals owned by these companies were constructed in 1881 and 1882 and as it was realized from the start that a sufficient supply of water could not be obtained by direct appropriation the construction of reservoirs was begun immediately. The third class includes the reservoirs owned by cooperative companies and supplying water to stockholders under canals which act as common carriers. Usually there is no legal connection between the reservoir company and the canal company, but in many cases a majority of the stockholders of the two companies are identical.

Reservoirs in the valley are supplied by natural streams; by seepage from canals, irrigated land, and other reservoirs; and by runoff from some normally dry catchment area during torrential rains. The great majority of the larger reservoirs take their supply from the Cache la Poudre and its tributaries, but a number are also supplied wholly or in part with foreign water. With the extension of irrigation, seepage from canals, reservoirs, and irrigated lands becomes important as a source of supply and many small reservoirs are now almost wholly dependent upon it. Only a few reservoirs are de-

pendent on the direct run-off from torrential rains, but most of this run-off is caught and stored.

The majority of reservoir sites were natural depressions or basins on bench land which were developed by putting the outlet in a cut, throwing up an embankment along the lowest rim, and constructing short inlet and outlet canals, connecting with distributing canals. These sites were the most satisfactory to be found, and were developed at a very low cost, running in one instance to $1.09 per acre-foot of capacity. Sites developed by the construction of a dam across a drainage channel which carries regularly little or no water are almost as numerous. They differ from the ordinary stream-bed reservoir in that they are filled from some nearby source through an inlet canal and their dams are rarely protected with spillways. Reservoirs in the channels of flowing streams are few in number, because more satisfactory and cheaper sites are usually available elsewhere. The majority of the sites developed were small, with rather steep slopes, the average capacity per foot of depth being close to 130 acre-feet. Bottoms vary from light soils through which there is considerable seepage to a compact clay loam which is practically impervious.

The dams are, almost without exception, earth fills, varying in height from 10 to 40 feet, set on earth foundations. In general the site of the dam was first cleared of all brush, roots, and stones, and then plowed, after which the material was put on in layers, levelled, sprinkled, packed, and then harrowed to form a bond with the layer above. Some of the first dams were carried up in layers as thick as 5 feet, but as the practice improved the layers were reduced to a foot in thickness. The travel of the teams was depended upon, usually, to do the packing.

An exception to the common type of dam in the valley is the Halligan Dam of the North Poudre Irrigation Co. shown in Plate XVI, figure 1. This is an arched concrete structure which impounds 6,428 acre-feet of water in the bed of the North Fork. Its length at the top is 350 feet and at the bottom 235 feet. The thickness ranges from 30 feet at the bottom to 3 feet at the top. The total height of the structure is 94 feet, and the depth of water stored is 69.8 feet. A spillway is located in the middle of the dam. It is 110 feet wide, 10 feet below the top, and has a curved lip designed to prevent the overflow from leaving the face of the dam under anything less than an 8-foot head. The lower 67 feet of the dam is cyclopean masonry, rock masses not exceeding 2 cubic yards in volume being imbedded in a 1:3:5 concrete, reinforced with steel bars. Because of the poor quality of the rock available the upper 27 feet of the dam is of straight 1:3:6 concrete reinforced with bars. The total cost of the dam was $230,000, which is at the rate of approximately $36 per acre-foot of capacity.

The earth embankments are of various dimensions. Crests are from 8 to 16 feet wide and usually carry a roadway. Outer slopes range between 2 to 1 and 4 to 1. Inner slopes are steep or flat, depending on whether they are well protected against wave action. The slopes paved with concrete are usually 1 to 1 or $1\frac{1}{2}$ to 1, while slopes with no protection are often as flat as 4 or 5 to 1. The freeboard maintained on the dams ranges from 1 to 15 feet and is usually a compromise between water requirements and safety. When possible it is the custom to fill the reservoirs only partly full in the early spring to permit them to pass through the period of high winds with a safe freeboard. After the danger from high winds is past they are topped out and the water is raised to a point on the dam which would be decidedly unsafe under a continued high wind.

The erosive action of waves on earth embankments, illustrated in Plate XVI, figure 2, is so destructive that some sort of protection is always provided if possible. A few of the smaller dams are protected by brush laid on the slope and held by stakes and wire. Many are protected by a loose rock riprap laid on the upper part of the slope, where wave action is most destructive. On the whole, this protection seems to give as much satisfaction as any. Its chief fault is that the rock is continually settling and slipping down the slope, making it necessary to add more rock until a condition of stability has been reached. In the case of the Cache la Poudre Reservoir more or less rock has been dumped on the slope every year for 20 or 25 years and a condition of strict stability has not yet been attained. A few slopes are protected by a rock riprap hand laid on a cushion of gravel. This type is also subject to dislodging and settling, and requires considerable repair work to keep it in good shape. A number of dams are protected by concrete pavements about 6 inches in thickness and reinforced with wire mesh or iron rods. Some of these are laid on in sheets without joints, but the majority are in strips running from toe to crest. A few are supported by ribs running up and down the slope at intervals. Owing perhaps to the short slopes covered, there have been no total failures of this type so far, but local failures are common. These failures start with cracks opened by expansion and contraction through which the water is able to dig a cavity in the slope under the pavement. After these cavities are formed it is supposed that the force of the waves either smashes in the unsupported pavement over the cavity or compresses the air in the cavity sufficiently to produce an outward bulge of the pavement and consequent failure. Plate XVII, figure 1, shows a break in the pavement of Terry Lake resulting from a crack.

As the great majority of the reservoirs in the valley are supplied through canals and with few exceptions the drainage area immediately above develops only a small amount of water, wasteways are

not considered necessary. The few that have been provided are simple makeshifts, usually depressions a foot or two above high water line which are left without embankment. The few dams in stream beds are of course properly equipped with spillways.

Outlets are either lines of tile or iron pipe or conduits of masonry or concrete. The pipe lines are all laid in concrete and are provided with concrete collars to cut off seepage. The masonry conduits are generally embedded in concrete and rest on solid foundations of concrete or masonry and concrete from 1½ to 5 feet in thickness. Gate wells are ordinarily at the top of the inner slope, as gates set either at the upper or lower end of the conduit have proved to be less satisfactory. Plate XVII, figure 2, shows the gate tower of the North Poudre Reservoir No. 15 blasted out after it had been replaced by a well within the dam as shown. The was done as a matter of precaution upon order of the State engineer after a similar structure in Lake Loveland had been destroyed by ice pressure. Many of the reservoirs have no gate wells, the gate stem being brought up through the dam in 4 or 6 inch cast iron pipe. Gates are of various types, including iron-strapped wooden gates, sliding iron gates, and other more pretentious valves. Lifting devices are all some standard combination of screw and lever.

The total capacity of the reservoirs of the valley is over 150,000 acre-feet. The largest is the Windsor Reservoir, which holds between 17,000 and 18,000 acre-feet, and from this size they range downward to many which hold less than 5 acre-feet. Some have never been surveyed to determine their capacities, and little dependence can be placed in the capacity tables of a majority of those which have been surveyed. The work was often done in such a manner that errors show on the face of the table, indicating in one case that the reservoir for a few feet of its depth took the shape of an hourglass. It is believed that accurate capacity tables based on reliable surveys would aid materially in the operation of the canals carrying reservoir water and would eliminate to a great extent inequalities in exchanges and in the distribution as well.

The very low first cost of the majority of reservoirs in the valley is indicated by the figures shown in Table 28, which, with the exception of the average, are reproduced from a bulletin by C. E. Tait, issued by the U. S. Department of Agriculture in 1903.[10] The Fossil Creek and Cache la Poudre Reservoirs run much above the average for the reason that each required a high and long dam across a valley. The sites of North Poudre No. 2, North Poudre No. 3, and Coal Creek Reservoir were developed at such a low cost because they were natural basins requiring only an outlet in a cut

[10] Storage of Water on Cache la Poudre and Big Thompson Rivers, by C. E. Tait, U. S. Dept. Agri., O. E. S. Bul. 134.

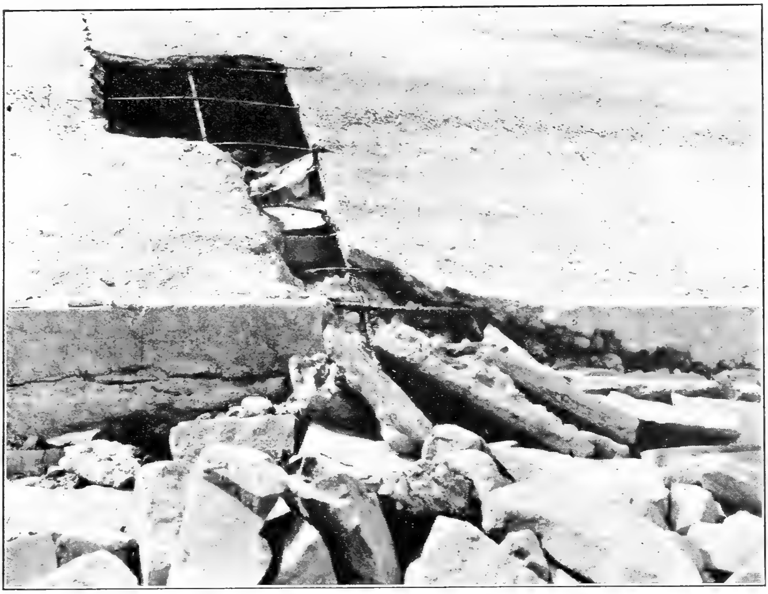
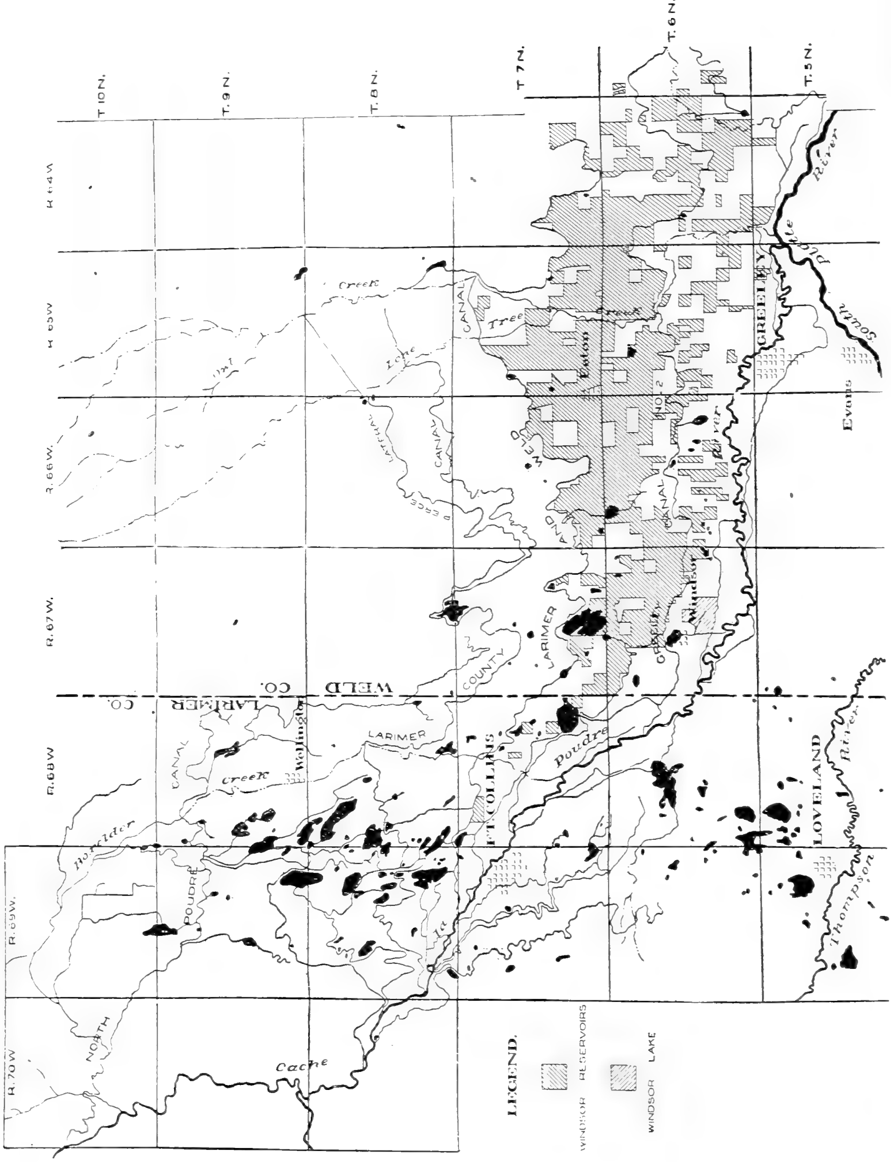


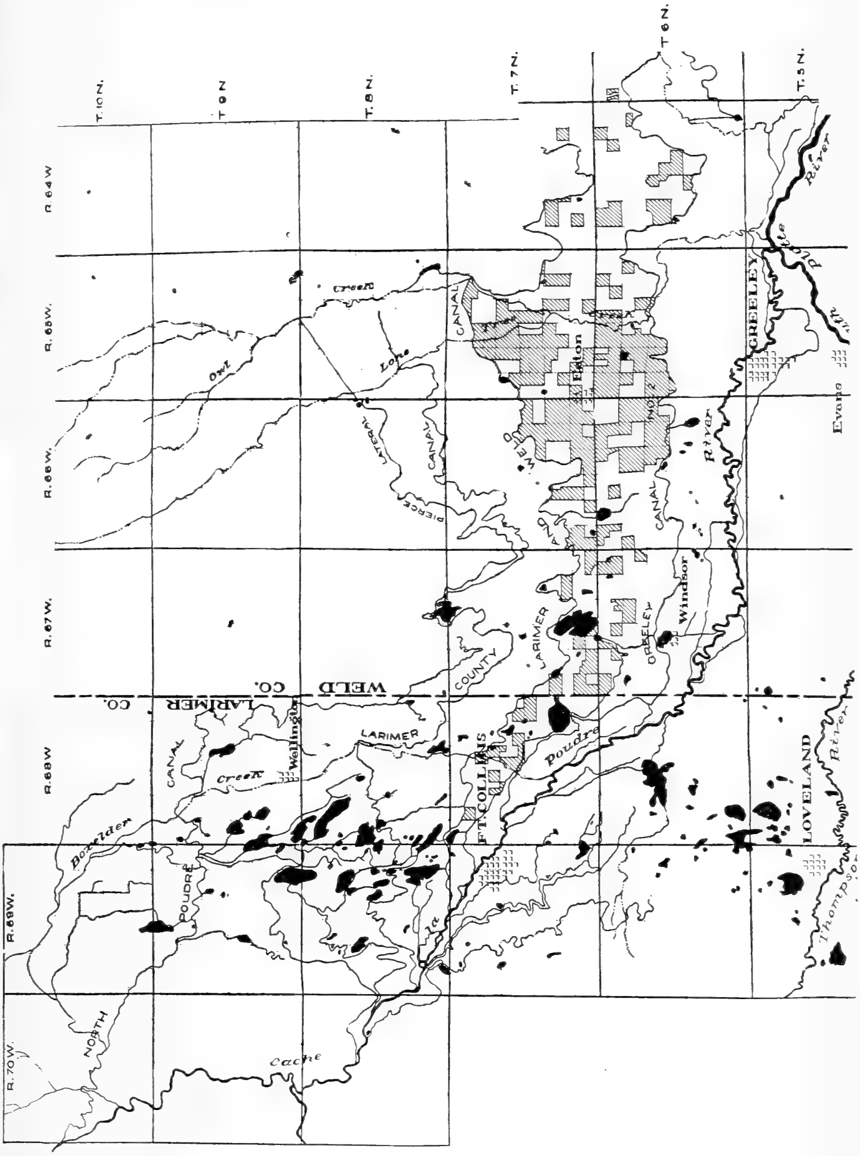
FIG. 1.—CLOSE VIEW OF BREAK IN THE PAVEMENT OF TERRY LAKE.

FIG. 2.—GATE TOWER BLASTED OUT AND REPLACED BY A WELL WITHIN THE DAM. NORTH POUDRE RESERVOIR NO. 15.

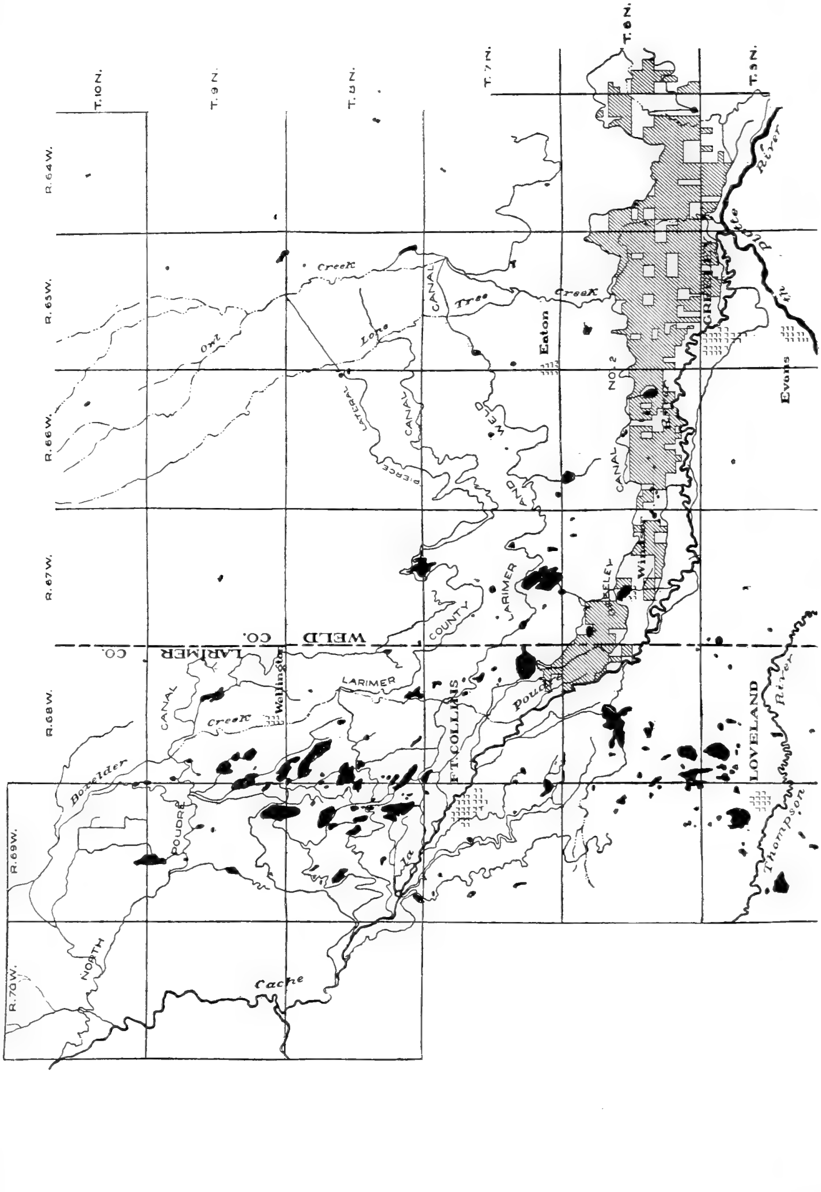
PLATE XVIII.



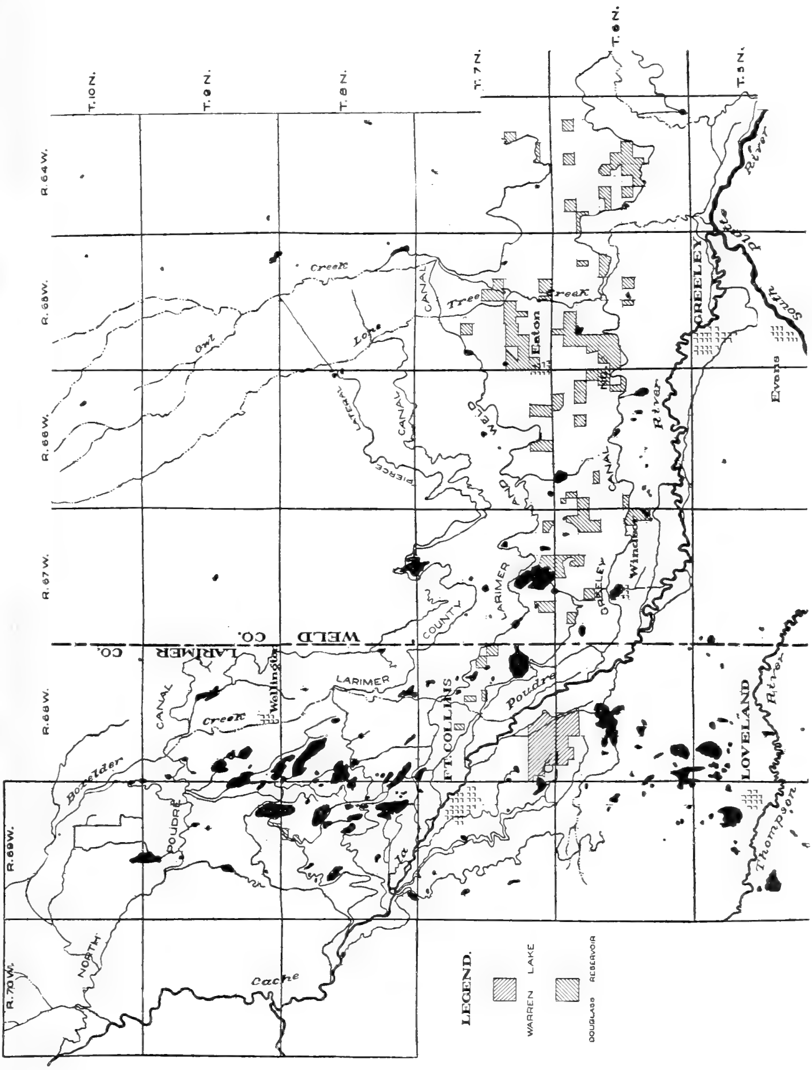
AREAS SERVED IN 1916 BY THE WINDSOR RESERVOIR AND WINDSOR LAKE.



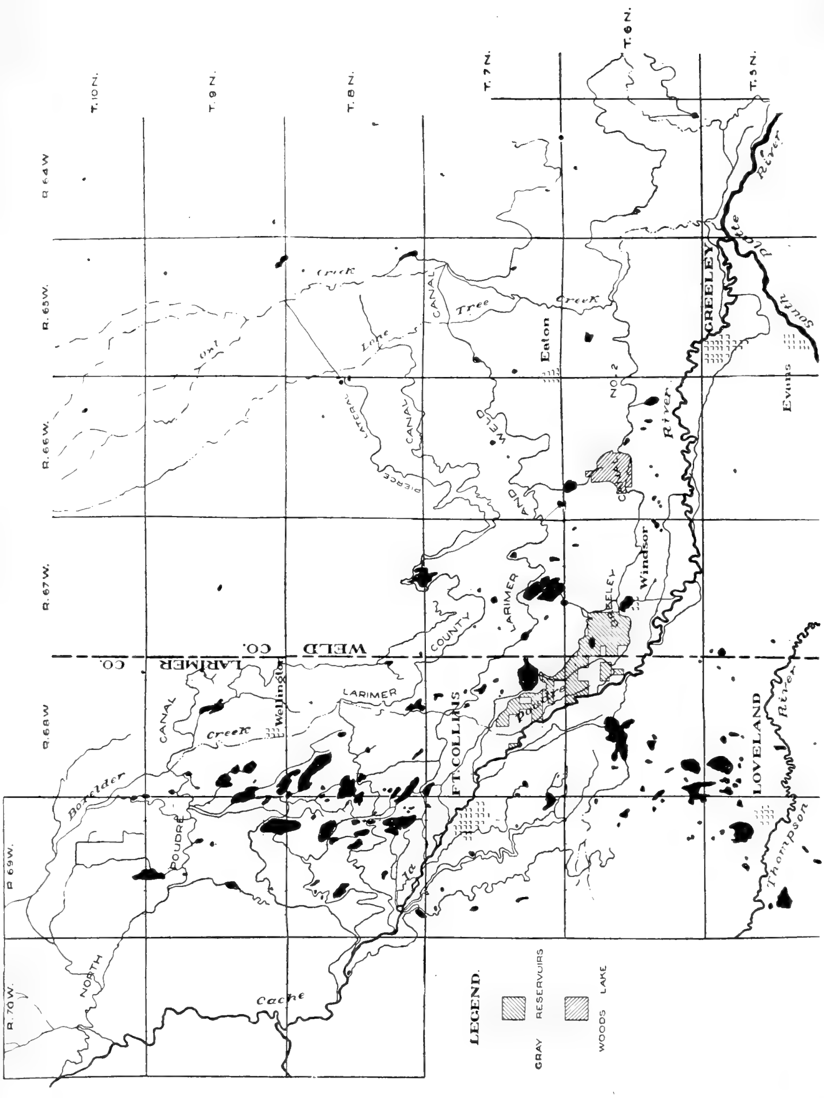
Areas Served in 1916 by Terry Lake.



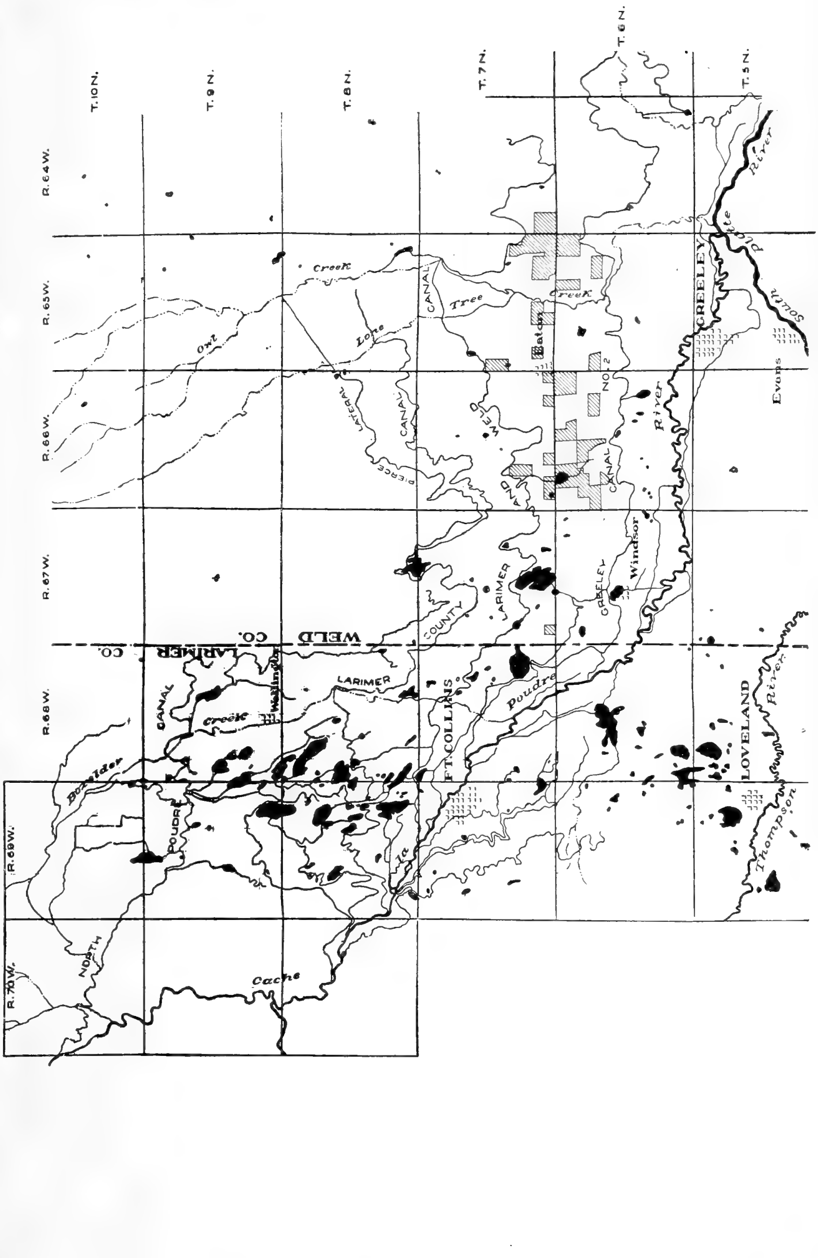
AREA SERVED IN 1916 BY THE CACHE LA POUDRE RESERVOIR.



AREAS SERVED IN 1916 BY WARREN LAKE AND DOUGLASS RESERVOIR.



AREAS SERVED IN 1916 BY THE GRAY RESERVOIR AND WOODS LAKE.



AREA SERVED IN 1916 BY THE WORSTER RESERVOIR.

and a small embankment. Some of these reservoirs have been enlarged since 1903 and the cost to date would give a lower unit cost than is shown by the table.

TABLE 28.—*First cost of reservoirs of the valley.*

Reservoir.	Cost.	Capacity in acre-feet.	Cost per acre-foot.
Cache la Poudre No. 2	$105,000	8,035	$12.07
Terry Lake (Larimer and Weld)	70,000	6,887	10.16
Windsor Reservoir	50,000	11,708	4.27
Rocky Ridge	12,000	4,726	2.54
Long Pond	12,000	3,922	3.06
North Poudre No. 1	3,000	674	4.45
North Poudre No. 2	7,500	5,000	1.50
North Poudre No. 3	5,000	2,550	1.96
North Poudre No. 4	5,000	1,074	4.66
Coal Creek (Clark's Lakes)	6,000	4,477	1.34
Fossil Creek	160,000	11,478	13.94
Douglass	50,000	10,547	4.74
Windsor Lake	1,000	918	1.09
Average			6.75

The sale of reservoir water and the rental of rights for a season is a common practice in the valley. Many reservoirs are owned by individuals and were built expressly for the purpose of selling the water stored in them, while others are owned by cooperative companies which impose no restrictions as to where the water may be used. Many farmers own an excess of rights in these reservoirs, and others have an excess when their scheme of rotation of crops brings them around to a year in which they have a preponderance of crops requiring only early irrigation. To offset this supply there is always more or less demand from farmers who have not quite enough water for ordinary conditions and who suffer from a real shortage in dry weather, or from farmers who have a sufficient supply in average years but who are growing a large acreage of crops requiring heavy late irrigation. In ordinary years under the Greeley Canal No. 2, a second-foot for 24 hours will sell for $5, and there will be an additional charge of $1 for carriage in the canal, but in dry years the price may be as much as $16 per second-foot for a day. Rights in Terry Lake, carrying between 45 and 50 acre-feet per season, have rented for from $40 to $300, but the average charge is close to $75. North Poudre shares, carrying 1½ to 2½ acre-feet, average about $10 per season. It is natural that under these conditions there should be a certain amount of speculation. In the early spring the speculator buys water or rents rights to be held and later rented or sold to others. Whether he makes or losses depends chiefly on the dryness of the season. Water for which he paid $2 an acre-foot may sell for $8 or $10, or there may be no market at all for it.

The land served in 1916 by the more important independent reservoirs of the valley is shown in Plates XVIII to XXIII, inclusive.

Water stored in reservoirs owned by canal companies is used on the same land as the direct flow of the canals, and these areas are shown in another section of this report. An estimate of the acreage actually irrigated by the independent reservoirs is given in Table 29.

TABLE 29.—*Estimate of acreages actually irrigated by independent reservoirs of the valley in 1916 and 1917.*

	1916						1917					
	Alfalfa.	Sugar beets.	Potatoes.	Beans.	Miscellaneous.	Total.	Alfalfa.	Sugar beets.	Potatoes.	Beans.	Miscellaneous.	Total.
Windsor Reservoir	18,663	9,741	5,443	4,096	......	37,943	14,647	5,227	9,182	5,734	......	34,790
Terry Lake	9,740	4,252	3,519	1,655	......	19,166	7,358	2,323	5,022	2,395	......	17,098
Cache la Poudre Reservoir	10,511	7,160	1,835	2,564	......	22,070	9,818	4,324	4,078	3,993	40	22,253
Douglass Reservoir	4,078	2,244	1,244	1,034	......	8,600	2,358	816	1,136	791	......	5,101
Warren Lake	1,330	681	......	9	17	2,037	1,485	656	2	4	19	2,166
Gray Reservoirs	1,741	1,336	35	74	......	3,186	1,696	1,161	76	78	2	3,013
Worster Reservoir	3,126	1,450	872	503	......	5,951	3,807	1,503	2,344	1,233	......	8,887
Woods Lake	329	168	161	82	......	740	252	198	222	231	1	904
Windsor Lake	186	439	......	30	......	655	152	303	23	34	......	512
Dowdy Reservoir	126	45	......	12	......	183	364	156	206	154	......	880
Hour Glass Reservoir	236	155	194	102	......	687	......	......	......	......	......	......
Zimmerman Reservoir	106	111	52	......	......	269	......	......	......	......	......	......
Greeley-Poudre Water	536	238	104	324	......	1,202	376	65	232	263	......	936
Fossil Creek Reservoir	2,920	2,063	700	1,155	......	6,838	2,794	1,178	1,472	1,579	......	7,023

Stored water is used for irrigation during every month of the season, but the greater part of it is used from July 20 to September 10, as the supply received on direct appropriations falls off. The amount of stored water used in 1916 and 1917 is shown in Table 30, which is taken from Tables 10 and 11 on pages 44 and 45. The large amount used in August, 1917, was due to a supply greatly in excess of the normal.

TABLE 30.—*Reservoir water used by canals of the valley in 1916 and 1917.*

	1916		1917	
	Amount used (acre-feet).	Per cent of total.	Amount used (acre-feet).	Per cent of total.
April	353	....	....	....
May	6,978	8	182	....
June	6,639	8	2,358	2
July	27,098	30	13,713	14
August	32,149	35	60,224	63
September	17,373	19	20,890	21
Total	90,590	100	97,367	100

ABSORPTION LOSSES.

In arriving at the absorption loss for reservoirs of the valley, reliable records of the following were used: Windsor Reservoir, Douglass Reservoir, Cache la Poudre Reservoir, Terry Lake, North

Poudre Reservoir No. 15, Woods Lake, Kluver Lake, Curtis Lake, Claymore Lake, Water Supply and Storage Co. Reservoir No. 4, and Dealy Reservoir. These reservoirs afforded a range in surface area up to 1,000 acres, in depth up to 40 feet, and in volume up to 17,500 acre-feet. Records were kept of the operation of all the more important reservoirs of the valley, but many of these records were not suitable for computing absorption losses and were discarded. No capacity tables were available for a number, and time could be found to survey only a few of these. Other records covering periods of inflow and outflow were discarded on account of the poor conditions at the measuring stations on the inlet and outlet canals. Thus in the case of Terry Lake the rating stations on both inlet and outlet were subject to backwater conditions and for that reason the only records of Terry Lake used in computing losses were those made during periods of no inflow nor outflow.

Table 31 is given to show the method used in computing the loss, and practically explains itself. In estimating the increase in the reservoir by rainfall it was necessary to use the rainfall records at Fort Collins, which is as much as 15 miles from some of the reservoirs, together with the area at the high water line and the probable run-off from the drainage area above. For this reason some of the periods overlap, the shorter excluding rains which show in the longer period and serving as a check.

The average absorption loss is shown by curves in figures 14, 15, and 16, in which the loss in acre-feet per day is plotted against the depth, area, and volume. The curves are based on more than 200 points, each of which represents the loss in a single reservoir for a period of from 3 to 30 days during the spring and summer months.

TABLE 31.—*Absorption losses from Claymore Lake.*

Period.	Days.	Reservoir gage at beginning.	Reservoir gage at end.	Average depth (feet).	Average surface area (acres).	Average volume (acre-feet).	Stored at beginning (acre-feet).	Increase by rainfall (acre-feet).	Total (acre-feet).	Stored at end (acre-feet).	Absorption losses. Total (acre-feet).	Absorption losses. Per day (acre-feet).	Absorption losses. Cubic foot per square foot of surface per day.	Absorption losses. Per cent of volume per day.
1916.														
June 1–28	27.31	14.54	13.77	14.16	79.0	893.3	923.6	4.2	927.8	862.9	64.9	2.38	0.030	0.266
June 14–28	13.98	14.21	13.77	13.99	78.6	880.3	897.6	......	897.6	862.9	34.7	2.48	.032	.282
1917.														
May 8–26	18.00	14.78	14.65	14.70	80.3	936.2	939.8	18.5	958.3	932.6	25.7	1.43	.018	.153
May 12–19	7.00	14.66	14.53	14.60	80.0	928.1	933.4	......	933.4	922.8	10.6	1.51	.019	.163
June 2–30	28.00	14.70	14.08	14.39	79.6	912.0	936.6	......	936.6	887.3	49.3	1.76	.022	.193
July 4–28	24.00	13.99	13.50	13.75	78.1	861.0	880.3	6.0	886.3	841.7	44.6	1.86	.024	.216
July 11–21	9.85	13.91	13.64	13.78	78.1	863.4	874.0	......	874.0	852.7	21.3	2.16	.028	.250
Aug. 1–11	10.04	13.38	13.11	13.24	76.9	822.2	832.5	.2	832.7	811.9	20.8	2.07	.027	.252

The amount of storage required for any particular canal depends on the amount of water produced by the direct flow rights at various times throughout the season and on the kinds of crops grown. This is shown by data for 1916 and 1917 for the four largest canals of the valley in Table 32. The comparatively small amount of stored water required by the Larimer County Canal is due to the fact that the greater part of its deficiency on direct appropriations is made up by foreign water. In the case of the North Poudre Canal the supply was short and more reservoir water could have been used to advantage.

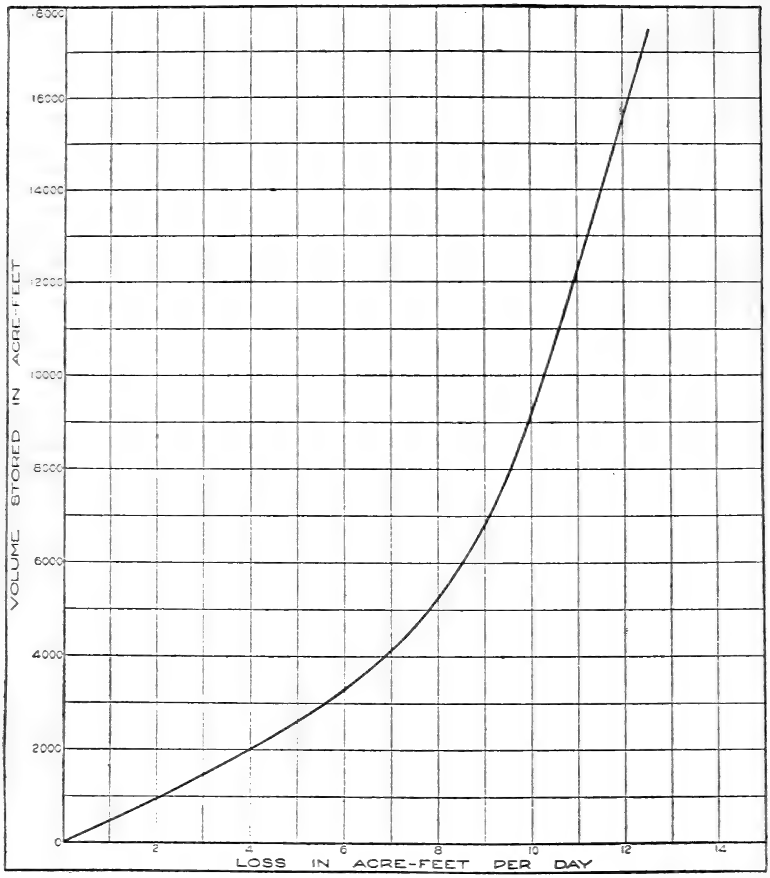


FIG. 14.—Absorption losses in reservoirs. Relation between the volume stored and the loss.

TABLE 32.—*Comparison of stored and direct flow water used by four of the largest canals of the valley in 1916 and 1917.*

Canal.	Priority No. of principal appropriation.	Water used.		Storage as per cent of total.
		Direct flow acre-feet.	Storage acre-feet.	
1916.				
Greeley Canal No. 2	37	54,908	13,458	20
Larimer and Weld Canal	88	67,166	23,926	26
Larimer County Canal	97	49,876	22,111	31
North Poudre Canal	98	16,169	25,188	61
1917.				
Greeley Canal No. 2	37	53,383	14,617	21
Larimer and Weld Canal	88	67,889	29,547	30
Larimer County Canal	97	64,692	19,274	23
North Poudre Canal	98	20,745	28,954	58

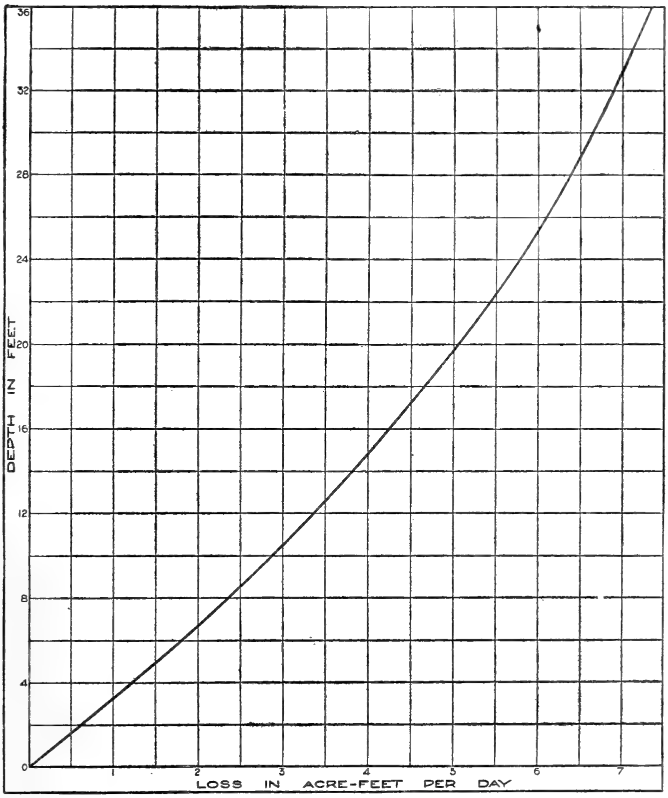


FIG. 15.—Absorption losses in reservoirs. Relation between the depth and the loss.

FARM RESERVOIRS.

A large number of reservoirs of the valley may be properly classed as farm reservoirs. They are owned by the individual farmer and are used by him to hold temporarily his supply of water from some

canal or to collect some small seepage stream to make it available for irrigation.

A typical reservoir of this class is owned by M. W. Dealy and supplies a part of his farm 7 miles northwest of Fort Collins. It is 8.6 feet in depth, covers 7.6 acres at the high-water line, and has a capacity of 26.6 acre-feet. The outlet gate of the reservoir is shown in Plate XXIV, figure 1. The dam is several hundred feet long, 8.5 feet

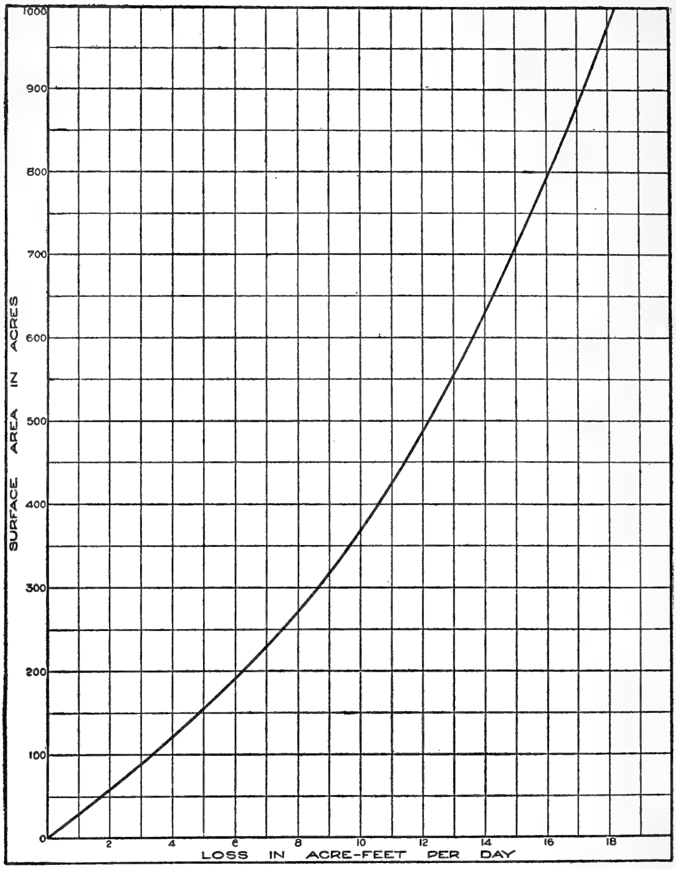


FIG. 16.—Absorption losses in reservoirs. Relation between the surface area and the loss.

high, and 10.5 feet above the outlet. The inner slope is riprapped with loose rock extending 5 feet below the high-water line. The outlet is 12-inch vitrified pipe set in a concrete bulkhead at each end. The gate is a common type of sliding iron gate. The reservoir was built in 1908 and cost $930, or at the rate of $35 per acre-foot of capacity.

Its water supply comes from the Larimer County Canal. A part of the Dealy farm is served by the Jackson Ditch, but a part lies above this ditch and is commanded only by the Larimer County Canal

of the Water Supply & Storage Co. In order to get a water supply for it, Dealy entered into a contract with the Water Supply & Storage Co. by the terms of which the company acquired half a share of stock of the Jackson Ditch from Dealy and Dealy acquired the right to a certain amount of water from the Larimer County Canal from April 15 to September 15 of each year. The contract provides that the amount delivered shall be approximately 17 per cent less than the amount per half share delivered by the Jackson Ditch the same day. When the Jackson Ditch draws all its appropriations a share represents 120 statute inches; therefore, the maximum amount Dealy is entitled to draw is 50 inches. Shortly after Dealy finished his reservoir the owner of an adjoining farm made a similar contract with the Water Supply & Storage Co. and purchased from Dealy a right to carry his water through the Dealy ditches. This water is carried directly through the reservoir.

During the season 1916, from May 8 to September 7, the Larimer County Canal delivered to the reservoir 211 acre-feet at a rate not exceeding 2.12 second-feet. This was sufficient to fill the reservoir eight times. The loss in the reservoir during the season was 39 acre-feet, or about 18 per cent of the total supply, including 4 acre-feet of rainfall and run-off. During the season 176 acre-feet were drawn from the reservoir for the irrigation of 99.3 acres of grain and alfalfa. The rate of use ran as high as 9.20 second-feet but averaged 5.44 second-feet for alfalfa and 3.25 second-feet for grain.

The difference in inflow and outflow noted above and illustrated in Plate XXIV, figures 1 and 2, reveals the chief benefit derived from these small reservoirs. A very high duty is obtained by storing streams of ditch and seepage water entirely too small for practical use and when the water is needed turning it out in large heads for effective and economical irrigation.

SUMMARY AND CONCLUSIONS.

The characteristics of the climate of the valley are a light rainfall, a wide range in daily and seasonal temperature, low relative humidity, moderately high wind movement, and a comparatively low rate of evaporation. The heaviest rainfall occurs in the spring and is usually sufficient to start the crops growing under natural conditions without resorting to irrigation to bring up the crops.

The prevailing type of soil is a light sandy loam, which is generally well drained. Excepting local phases, the texture of this soil is such that it is easily irrigated and at the same time it retains moisture well. The average depth of water applied for an irrigation is close to .75 foot, but the average is raised somewhat by the heavier irrigations applied when direct flow water is available in order to reduce the later requirements of stored water. Considering the soil

alone, best results would be obtained by quick irrigation to a depth of 0.4 to 0.6 foot.

The water supply of the valley averages 464,000 acre-feet, which includes 340,000 acre-feet of normal run-off in the river and its tributaries, 35,000 acre-feet of foreign water, 5,000 acre-feet pumped from wells, and available seepage return to the amount of 84,000 acre-feet. Practically the whole supply is taken; and further projects, either for direct flow or for storage, are probably not feasible.

The regimen of the river largely controls the cropping system of the valley. The flood stage of the stream occurs at such a time that the irrigation of at least a third of the acreage in crops, chiefly grain, may be completed with water drawn directly from the river. This leaves the stored water to be used for maturing such valuable crops as sugar beets, potatoes, etc.

The foreign water brought into the valley from other drainage basins is collected from the highest slopes of the mountains, and it therefore comes down after the peak of the flood has passed. This supply is comparatively small but it is very vital to both the North Poudre and Larimer County canals. It becomes available shortly before their main appropriations are cut off and makes it possible to delay for from one to three weeks the time when almost the whole demand must be met with stored water.

The total seepage return in the valley is 137,000 acre-feet, which is approximately 36 per cent of the normal water supply (exclusive of seepage). The topography is such that a large proportion of this seepage return is available for use, and it plays an important part in irrigation in the valley. The high percentage of return indicates that when the return reaches the maximum on other streams many water rights, both direct and storage, which are now not dependable, will become good. The certainty and uniformity of this supply will produce results comparable to those produced by stored water.

Drainage is not a serious problem in the valley. Only local areas have become too wet, and corrective measures have always been promptly applied.

By the system of exchange of water developed in the valley 50,000 acre-feet of stored water is made available for use in canals above the reservoirs. To this system may be attributed the use of a number of sites capable of cheap development. Incidentally, as perfected in the valley, the system promotes a better distribution from the river and vastly improves conditions under which the canals operate by largely confining the daily fluctuation of the river to one of the larger canals where it can be "smoothed down" by the use of reservoirs as regulators. In addition, the pooling of interests required by the exchange has brought about a better understanding between the canal men of the valley and there is now a tendency to get to-

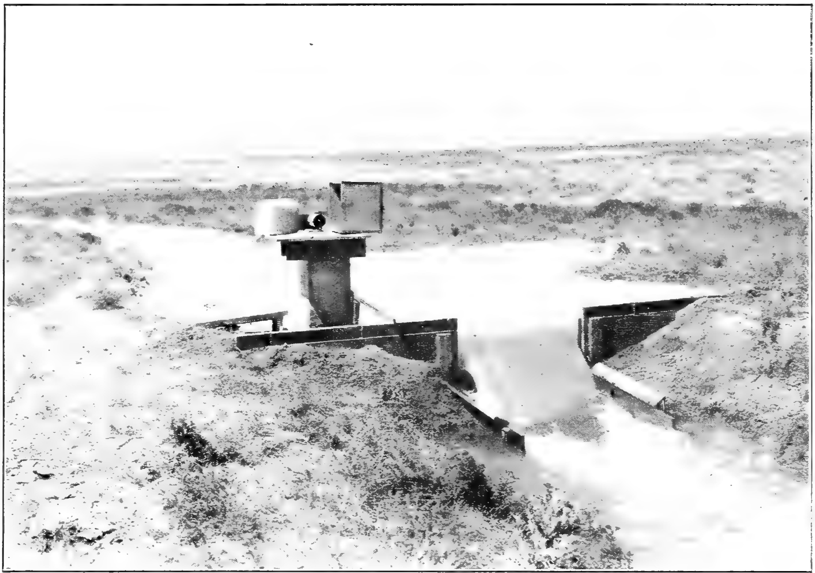


FIG. 1.—WEIR ON THE OUTLET OF THE DEALY RESERVOIR. AVERAGE OUTFLOW.

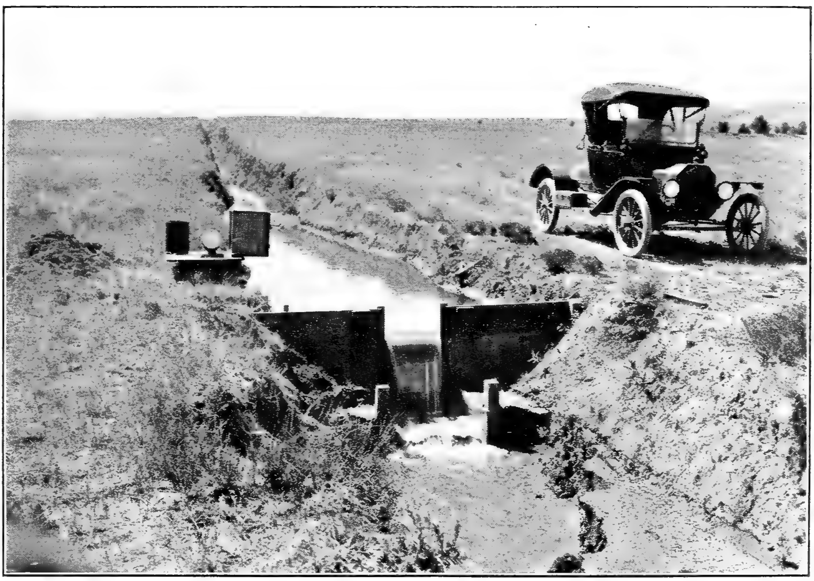


FIG. 2.—WEIR ON THE INLET OF THE DEALY RESERVOIR.

gether and talk over differences before resorting to the law. There is no doubt that the practice of exchanging water had its effect in getting the canal men of the valley in the habit of measuring water. While conditions of which the system is an outgrowth will probably never be duplicated, the principles and methods involved might be advantageously applied for a solution of problems elsewhere.

The majority of direct flow rights of canals were established by decree of the district court in 1882 and these rights remain practically unchanged. Storage rights were fixed by decree in 1909. There can be no question that the early fixing of rights had a strong influence on the later development of irrigation. The canal owners whose decreed rights were good went ahead with their development and expansion secure in the feeling that they would be protected in their rights. The two late appropriators of large amounts were clearly shown the inadequacy of their rights and lost no time in devising means of supplementing their supplies. This led at once to the construction of reservoirs and later to the development of supplies of foreign water.

In the aggregate, capacities of the canals exceed by 10 per cent their appropriations. The extension of land irrigated has been such that the originally excessive decrees of the larger canals are now utilized. Excessive rights are still held by several small ditches along the river bottoms. These ditches divert a comparatively small amount, of which a great part returns directly to the river and is diverted below by canals with early rights.

Many transfers of appropriations from one canal to another have been made, but the amounts transferred, especially of the earliest rights, were small. These transfers have in general resulted in little damage to other appropriators and in much benefit to the canal to which the transfer was made.

Almost without exception distribution from the river is made in accordance with decreed priorities. The exceptions to the rule are recognized as legitimate by the canal men of the valley. Besides fearlessness and tact, the distribution of water from a stream requires an intimate knowledge of the handling of water in general and of the peculiarities of the particular stream itself. The water commissioner's handling of the Cache la Poudre for more than a score of years is most convincing evidence that the administrator of a stream should not be subject to the fortunes of a political party and that when a good man is secured he should be kept in office. It is folly to expect an inexperienced man to handle satisfactorily the problems of distribution which constantly arise, especially as complicated by return water and private water carried in natural channels. The obvious remedy is a study of the streams of the State by experienced

engineers and hydrographers to determine losses and gains in the streams, the return flow, characteristics of flow peculiar to each stream in flood and at low stages, and other pertinent facts. With this information at the disposal of the administrator a fairly satisfactory distribution would be possible immediately upon his taking office and not after 2 or 3 years of painstaking and perhaps costly experimenting.

The duty of water figured for the river as a whole is 1.67 acre-feet per acre; or, expressed differently, each second-foot of the average annual discharge irrigates 434 acres. This very high duty is made possible only by the reservoirs of the valley. To attain a duty as high without stored water, the crops grown would have to be limited to the grains.

The consumptive duty for the valley is estimated not to exceed 1.25 acre-feet per acre.

Nonproductive and waste land averages approximately 15 per cent of the area under irrigation.

The areas irrigated by the various canals lie in very compact bodies, which promotes to a pronounced extent the efficient use of the water supply.

The area actually irrigated in the valley proper in 1916 was 218,000 acres; in 1917, 225,700 acres. Any marked extension of the area irrigated is improbable.

The majority of the canals of the valley are cooperative enterprises and present no unusual features of organization. The fact that the majority were cooperative from the beginning has an important bearing on the development of the valley. Such systems were run for the mutual benefit of water users and there was very little of the paralysis of development caused elsewhere by overpromotion for profit.

The great majority of laterals serving more than 2 or 3 users are controlled by incorporated cooperative stock companies, and this form of organization for laterals is to be recommended. By it the delinquent water user can, in an impersonal way, be made to live up to his obligations.

Canal structures follow common designs and concrete is replacing wood for construction purposes. The systems of the valley have long since passed the stage of development where cheap construction was permissible in order to reduce first costs, to keep down interest charges, and to permit expansion. Future construction should be of the most substantial character.

The rating flumes of the canals are generally most unsatisfactory and should be replaced by structures better suited for the purpose. They should be of the same cross section as the canal and should neither constrict nor widen the channel. They should be on grade

and in a straight section of canal with no curves for some distance either above or below. The velocity through them should be sufficient to prevent the deposit of silt, but not high enough to produce waves. There should be no drop immediately below to produce standing waves. They should not be subject to backwater from movable checks, and they should not be placed close below gates which either do, or may be made to, discharge under pressure.

Maintenance problems are at a minimum. However, more attention should be paid to protecting canal banks from erosion, installing effective sand traps, and keeping delivery weirs in better order.

The distribution within the canal system of direct flow water is either by continuous delivery of a prorata part of the flow or by some system of rotation when the supply is short. The latter system is by far the most effective in producing a maximum benefit from a given supply. The other system is almost invariably a source of waste.

Reservoir water is delivered as a prorata part of the flow carried, or in rotation, or on demand. Delivery on demand produces the most effective use but at times the advantages must be weighed against difficulties of canal operation.

Many canals act as common carriers for reservoir water owned or rented by their stockholders. By a system of pooling of interests and switching of credits this water is delivered on demand of the individual.

Weirs are used for measuring water to the user but there is much room for improvement in their installation and maintenance.

The average gross duty of water measured at the head of all the canals of the valley was 1.88 acre-feet per acre in 1916 and 1.91 acre-feet per acre in 1917. Taken in connection with the consumptive duty of 1.25 acre-feet per acre, this indicates a total loss exclusive of evaporation of only a third of the supply.

The absorption loss in the canals of the valley between the head-gate and the farm lateral is estimated to average 10 per cent of the supply. This low figure is accounted for in part by the topography of the country and the location of the canals one above another. A considerable part of the gross loss is compensated by the inflow of seepage.

Seepage water is used to some extent on nearly the entire irrigated acreage of the valley; but the land dependent on it as a main supply is rather limited, unless we include that lying under the ditches which divert it after it has returned to the channel of the river.

Furrow irrigation and flooding from field laterals are the only methods of irrigation practiced. Best results are obtained by a fast irrigation to a depth of .4 to .6 foot. The layout of the field should be such that a thorough even watering is obtained, that there is a minimum of run-off at the lower end of the field, and that the depth

applied is light enough to prevent an undue loss by deep percolation. The head used should be governed by the conditions above and the soil. Large heads should be used when possible, as they save both time and water if handled properly.

The run-off from the lower end of the field averages 6 per cent of the amount applied. This is a very low average, but there are many farms where much improvement could be made along this line.

The average number of irrigations applied on the fields under investigation ranged from 1.21 for wheat to 3.79 for potatoes.

The average head used by one irrigator ranged from a minimum of 1.85 second-feet for sugar beets to a maximum of 2.59 second-feet for alfalfa.

The number of acres irrigated per day by one person ranged from an average of 4.45 for barley to 6.78 for potatoes. Beans were in an entirely different class with an average of 15.63 acres per day per man.

The average duty in acre-feet per acre, measured at the head of the farm lateral, was: Alfalfa, 2.57; wheat, 1.04; oats, 1.35; barley, 1.19; sugar beets, 1.86; potatoes, 2.20; beans, 0.69.

Reservoirs are by far the most important factor govering the good use of water in the valley. By their use water is made available when and only when needed. Without them an entirely different type of development would have resulted in the valley.

The large number of reservoirs was made possible by natural basins which could be developed with a minimum of trouble and expense. For thirteen of these reservoirs with an aggregate capacity of 72,000 acre-feet the average cost of development was $6.75 per acre-foot of capacity.

The majority of reservoir dams are low earth fills, and slopes are protected against erosion by rock riprap or concrete pavements. For these comparatively short slopes both types of protection have given satisfaction.

Gate wells are now placed in the dam at the top of the inner slope. Locating them either at the upper or lower end of the outlet was found to be unsatisfactory and at times dangerous.

Outlet conduits are generally of stone or concrete and are often in cuts through the rim of the natural basin forming the bottom of the reservoir.

The aggregate capacity of reservoirs with decreed rights from the main river is now in excess of the normal available supply and further new projects of that type are not feasible. Storage development in the future should be along the line of flood-control reservoirs high up on the stream by which the flow of the stream below could be made to conform to actual current irrigation requirements,

rather than as a matter of necessity making irrigation practice conform to the flow of the stream and future as well as current needs. Were the Cache la Poudre Valley alone concerned this could be accomplished by a general pooling of interests as in the case of the exchange, but no doubt appropriators on the South Platte below would object strenuously to such a radical departure from custom unless they could be shown that no invasion of their rights would result.

The system of independent ownership of reservoirs and the resulting scale and rental of rights which may be used at any point affords a better distribution and a certain elasticity of supply which is on the whole very beneficial.

The amount of irrigation after September 15 in the Cache la Poudre Valley is negligible, and considering this valley alone, storage of the supply in the river should begin at that time.

Under the system of diversified crops common in the valley a relatively small amount of stored water is required. For practically the entire acreage under irrigation in 1916 and 1917 less than 25 per cent of the supply used was stored water.

The many farm reservoirs holding a few acre-feet play an important part in promoting a good use of water and their construction is recommended to secure a maximum benefit from a small flow, either constant or intermittent.

Absorption losses are relatively highest in small shallow reservoirs and the proportion decreases markedly with the increase in the volume of water stored.

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